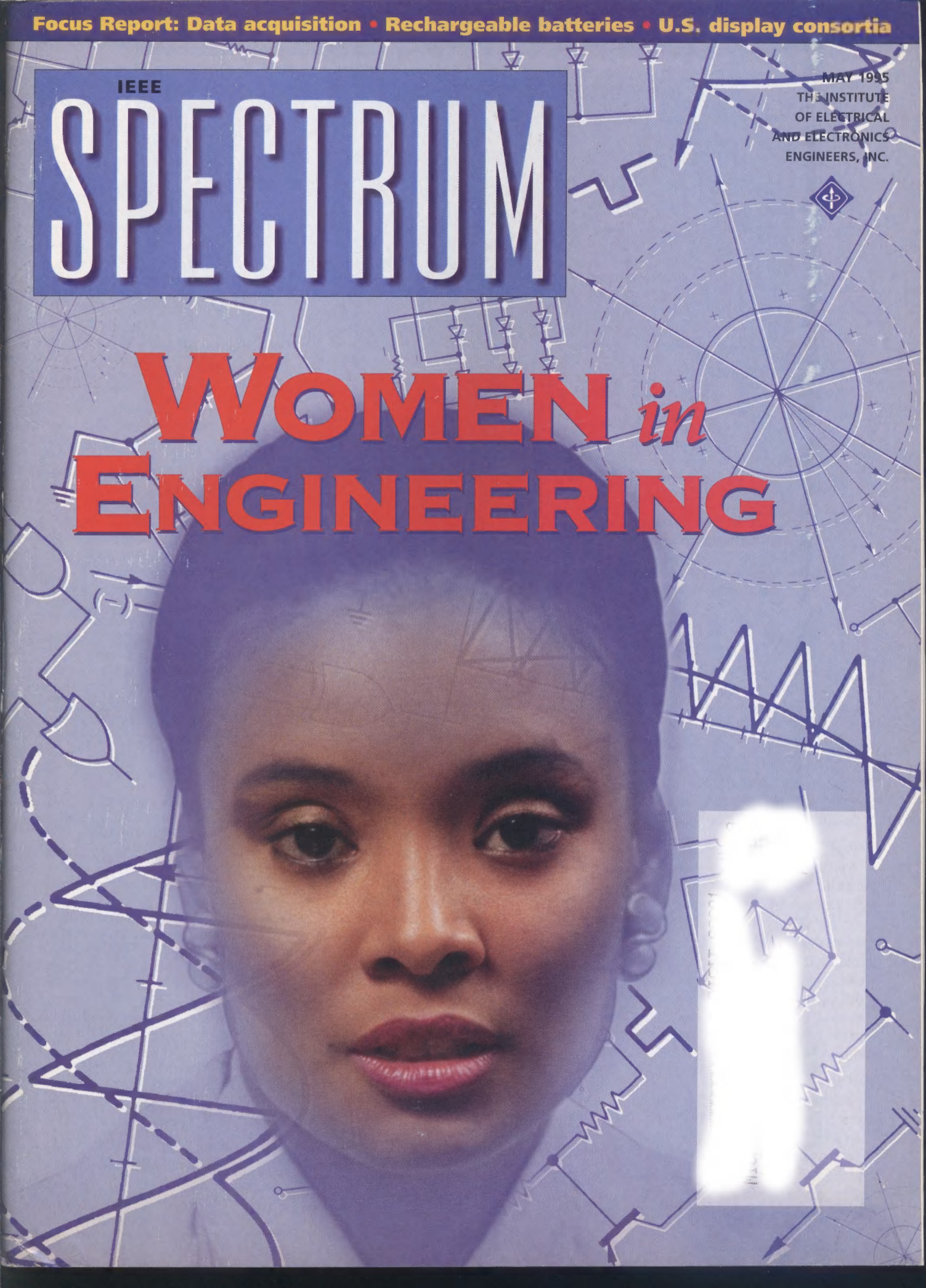
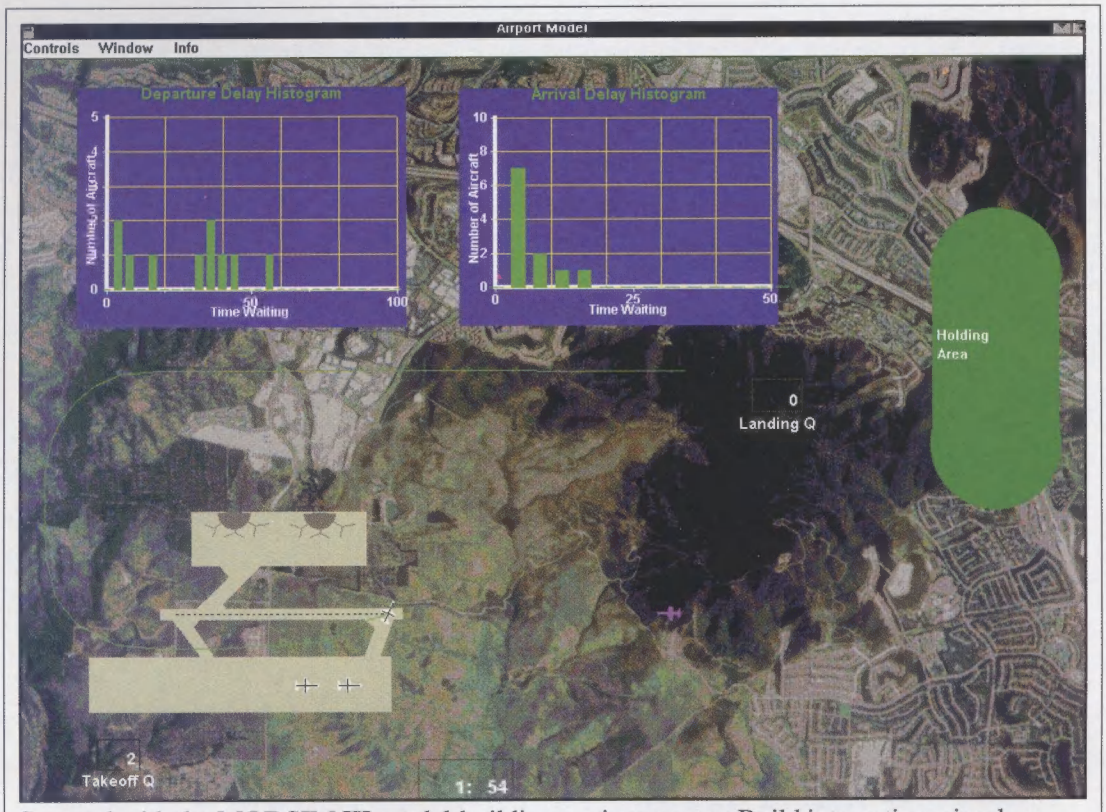
Focus Report: Data acquisition • Rechargeable batteries • U.S. display consortia

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newslog

MAR 13. The **U.S. government** said it had completed the biggest auction ever in selling part of the nation's frequency spectrum for US $7 billion to would-be providers of wireless networks for personal communications. Among the top winners: **Sprint Corp.**'s partnership with three big cable operators, which paid $2.1 billion for licenses in New York City and 28 other cities; **AT&T Corp.**, which put up $1.7 billion for 21 markets, including Chicago and Boston; and a joint effort of **Bell Atlantic**, **Nynex**, **US West**, and **AirTouch Communications**, which paid $1.1 billion for 11 markets, including Dallas.

MAR 13. New Mexico's **Mescalero Apaches** said that they had voted in favor of negotiating with the nuclear industry to store spent radioactive fuel on their reservation. If negotiations succeed, project manager Silas Cochise, great grandson of the Apache leader, will work with a consortium of 33 nuclear power operators to store 20 000 tons of spent nuclear fuel rods for 40 years, until a Federal disposal plan emerges. The consortium will pay the Apaches $250 million. [See related story, p. 19.]

MAR 13. Micron Technology Inc., Boise, Idaho, said it would build a $1.3 billion semiconductor plant in Utah County, south of Salt Lake City. The plant will employ 3500 people.

MAR 14. NASA said that astronaut, engineer, and physician **Norman E. Thagard** had become the first American to enter space on a Russian rocket. Thagard, **Vladimir N. Dezhurov,** and **Gennadi M. Strekalov** blasted off in a Soyuz spacecraft from Baikonur in Kazakhstan. Two days later they docked at the Russian Mir space station, for a stay of three months.

MAR 15. The **President's Advisory Committee on Human Radiation Experiments** said that documents from the Los Alamos National Laboratory in New Mexico show that the U.S. military knew of the health risks of radioactive fallout from nuclear bomb testing in 1951 and, though a safer site was available in Alaska, chose one near populated parts of Nevada to get better data on where the fallout would go. The Nevada Test Site is 100 km northwest of Las Vegas.

MAR 17. Judge Harold H. Greene of the Federal District Court in Washington, D.C., ruled that regional phone company **Bell Atlantic Corp.**, Philadelphia, could compete directly with cable operators and broadcasters by transmitting television programs anywhere in the United States. The ruling is expected to be extended soon to other Baby Bells.

MAR 17. Applied Materials Inc., which makes equipment for semiconductor manufacturers, said it plans to hire 2900 workers this year. Half of them will work at company headquarters in Santa Clara, Calif., and half at its factories in South Korea and Taiwan.

MAR 20. Novell Inc., Xerox Corp., and **Hewlett-Packard Co.** announced technology that will allow PC users to print documents at an office in another city or another company, and to receive on-screen messages about the progress of their printing jobs. Xerox and HP plan to be ready early next year with printers and copiers capable of working with the software, based on Novell's NetWare.

MAR 21. Germany's **Deutsche Telekom AG** said it had beaten three other international telecom groups to win a 25 percent stake in **Satelit Palapa Indonesia (Satelindo)** for $586 million. Satelindo competes with the state-owned Indosat group.

MAR 21. Loral Corp., New York City, said that it would buy the defense and aerospace operations of **Unisys Corp.**, Blue Bell, Pa., for $862 million. The deal allows Loral to improve its capabilities in satellite communications and in military information systems and frees Unisys to focus on information technology.

MAR 23. The **U.S. Senate Commerce Committee** said that it had approved a telecommunications overhaul bill that would allow local and long-distance telephone companies and cable television companies to enter each other's markets. Debate on the bill is expected to begin in the full Senate in May. The **House of Representatives** is also drafting its version of the bill, which is slated for July.

MAR 24. Cray Computer Corp., Colorado Springs, Colo., said it had filed for Chapter 11 bankruptcy court protection after it had failed to find the $20 million needed to complete building its Cray 4 supercomputer. The six-year-old company will lay off 340 employees.

MAR 28. Eastman Kodak Co., Rochester, N.Y., said it would allow its proprietary Photo CD system to be licensed by software developers. The company also announced alliances to help build its digital photography business, including one with **Microsoft Corp.,** to develop software for manipulating pictures on PCs, and with **Sprint Corp.,** to develop a system for transmitting images of data files over phone lines.

MAR 29. Russian officials said a converted nuclear missile carrying an Israeli and two Russian commercial satellites crashed into the sea 10 minutes after launch from Plesetsk in Russia's far east. A malfunction in the rocket's fifth stage was blamed.

MAR 31. IBM Corp. said it had set a world record in the laboratory for magnetic-data storage density. Its 5 Mb/mm^2 is nearly five times the density of the most advanced disk available today. Researchers achieved the advance by refining, shrinking, and improving magnetoresistive recording heads and ultralow-noise thin-film magnetic hard disks.

APR 1. The **U.S. Coast Guard** said it had turned off its **Morse code** equipment—used since the early 1900s—in favor of employing satellites and automatic navigation beacons to track Mayday calls at sea.

APR 3. Raytheon Co., Lexington, Mass., said it will pay $2.3 billion for **E-Systems Inc.**, Dallas, a military contractor that builds spying equipment.

APR 7. Ameritech Corp., the Baby Bell in Chicago, said it had received approval from the **Illinois Commerce Commission** to offer long-distance service on a trial basis in the Chicago and Grand Rapids, Mich., areas if it opens up its local markets to competition. The approval followed an April 3 announcement that the **U.S. Justice Department** had blessed the plan.

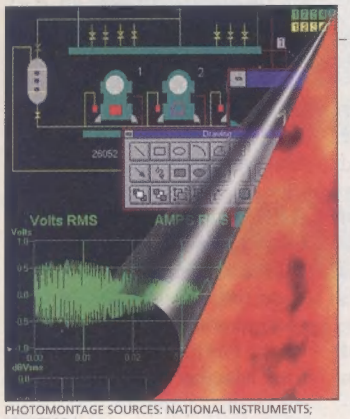
Preview:

MAY 31. By this date, the **Department of Energy** (DOE) is to release the draft of its Waste Management Programmatic Environmental Impact Statement. The report will be used to support decisions about treatment and storage of radioactive wastes at 40 DOE sites in 20 states. For information and free copies (including CD-ROM versions), call 800-736-3282.

SALLY CAHUR

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From turnkey packages to virtual instruments, today's tools help tackle the testing needs of increasingly elaborate systems.

24 Choosing the right data acquisition tool

BY RICHARD HOUSE

Checking software for flexibility and ease of use, often mutually exclusive characteristics, can guide the engineer or scientist in the selection of the right tool for a given application—more than 50 packages are tabulated.



JERRY VALENTE

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40 No rose garden for women in engineering

BY LINDA GEPPERT

A roundtable of women engineers agrees that the profession is technically rewarding, but that gender bias, isolation, and lack of support from family, friends, and superiors keep women away.

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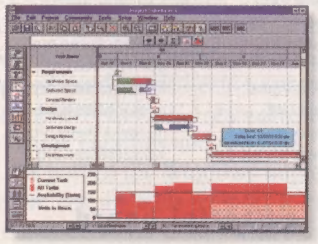
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And while no project management software will free you from being paged throughout the day, InfoWorld calls new Version 1.5 of Project Scheduler 6 for Windows *"a no-lose bet."*[1]

"Whether you're managing one project or a thousand, Project Scheduler 6 provides all the intricate task, budget, and report features of a high-end project manager in an intuitive, usable, and inexpensive package." writes PC Computing.[2]

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Circle No. 11

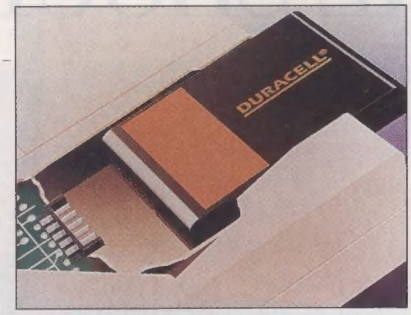
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technology

51 The search for better batteries

BY MICHAEL J. RIEZENMAN

The goal is units that deliver more than a couple of hours' worth of the 15–20 W required by today's hand-held computers. Affordable units will impact many other areas, too, from power tools to electric vehicles.

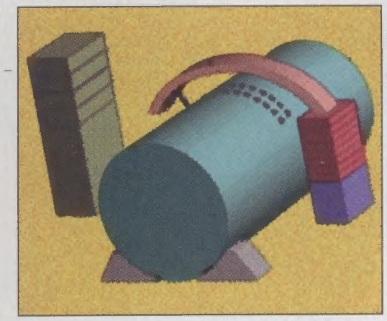


DURACELL INC.

57 Sleuthing out gravitational waves

BY MELVIN A. LEWIS

Because these waves are so weak, they are a tremendous challenge to the builder of any instrument meant to detect the phenomenon, such as a laser interferometer or this resonant-bar detector [right]. The huge solid metal bar with strain gages attached acts as an antenna for picking up the waves.



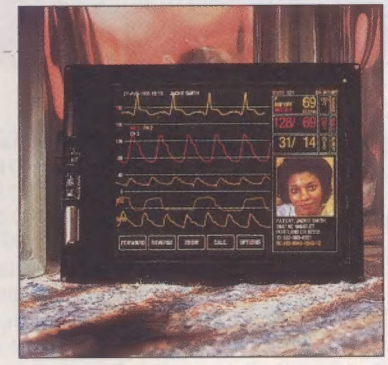
MELVIN A. LEWIS

perspective

62 U.S. consortia enter flat panel fray

BY KENNETH I. WERNER

Changes in the ways that displays can be fabricated and the military's wish for domestic suppliers is focusing attention on the United States' lack of capacity in this increasingly crucial technology.



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Trudy E. Bell	t.bell@ieee.org
Richard Comerford	r.comerford@ieee.org
Linda Geppert	l.geppert@ieee.org
Gadi Kaplan	g.kaplan@ieee.org
Tekla S. Perry	t.perry@ieee.org
Michael J. Riezenman	m.riezenman@ieee.org
Alfred Rosenblatt	a.rosenblatt@ieee.org
Murray Slovick	m.slovick@ieee.org
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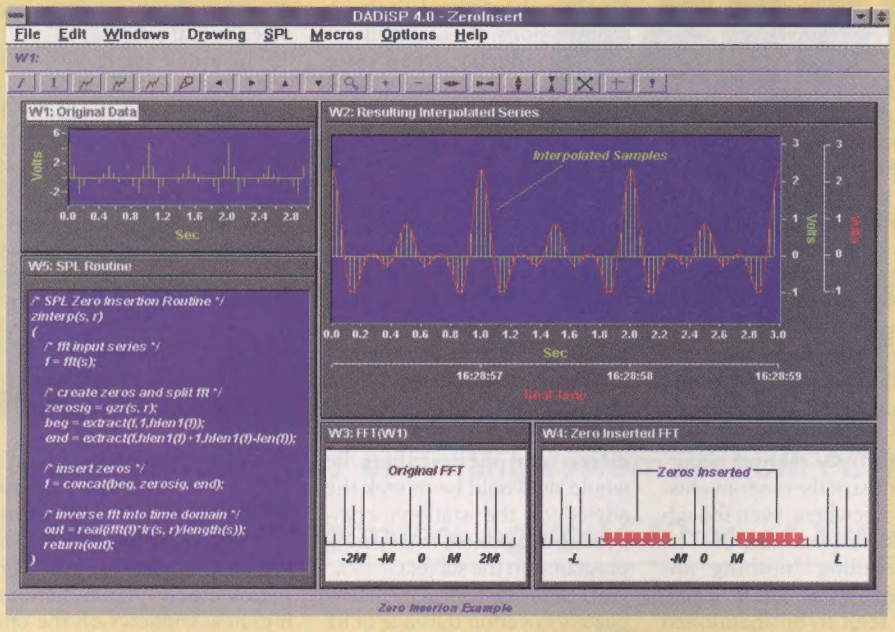
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IN CASE YOU MISSED IT!

Here's what they* said about DADiSP 4.0

A streamlined user interface that fully conforms to Windows is the first obvious feature of a long-awaited upgrade to DADiSP, a graphical analysis program from DSP Development Corp. that's designed for the needs of scientists and engineers.



A major overhaul of the user interface, the introduction of an integrated programming language and new option modules highlight Ver. 4.0 of DADiSP...

Besides adopting a complete Windows look and feel, the overall interface scheme has gained a more streamlined look... [W]ith the flattened hierarchy on this upgrade, the software always starts up in a worksheet; indeed, when loaded, the software returns to the setup that was on the screen when the user last exited the program. Although you don't have to go through a hierarchy, the package still maintains labbooks, datasets and worksheets to provide a simple method of organizing large complex datafiles and projects.

As part of the Windows implementation, Ver. 4.0 adds support for DDE as a client or server either with functions at the command line or with Copy/Paste Link for the pulldown menu. It performs both warm and hot DDE links with either ASCII or binary datatypes...

Ver. 4.0 also gives users the ability to define their own operations and functions to a far greater extent than the macros found in the previous version. Specifically, the upgrade marks the introduction of a programming language called SPL (series processing language). Modeled on C, it provides all the expected facilities including user-defined functions, looping and iteration, conditional statements, array references and variables. Variables can be global to a session or local to a function.

An interesting feature is the hot variable, which can contain real or complex numbers, strings, data series and matrices. A hot variable links a formula to a variable so that when a dependent element of a formula changes, the hot variable automatically reevaluates. For example, the SPL code fragment:

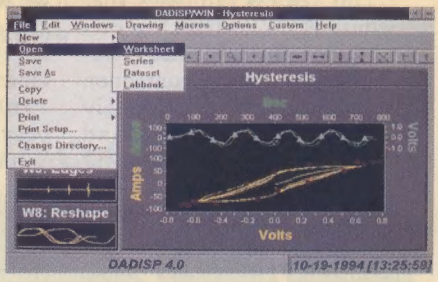
```
size := 10
W2: Movavg(W1, size)
```

performs a 10-point moving average on the waveform in Window 1 and displays the results in Window 2. The := operator establishes the hot variable. You can explore the effects of changing the moving-average length simply by reassigning size := 20 so that W2 automatically updates and shows a plot based on that new parameter.

Also improved is the package's hardcopy facility. Plot titles, legends, multiple scales, selectable fonts and a Preview mode help users produce publication-quality output...

[T]wo more modules... address advanced DSP and control applications. The AdvDSP module performs Chirp-Z transforms, N-point FFTs independent of series length and zoom FFTs. It also handles multiple forms of PSD estimation (classical, autoregressive parametric, moving-average parametric, autoregressive moving-average parametric), transfer-function estimates, Cepstrum analysis and digital interpolation. The controls module allows you to execute command line or pulldown menus, and it addresses the design, analysis and simulation of digital and continuous open- and closed-loop controllers for linear single-input/single-output dynamic systems. Among its algorithms are those that handle PID loops as well as lead and lag controllers.

* Personal Engineering & Instrumentation News 1/95



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Circle No. 6

forum

Engineers/Volunteers

I read with great interest the letter from Marta Viudez [March, p. 6] about volunteering engineering organizations in Spain and France. Here in Maryland, we have a group of engineers called Volunteers for Medical Engineering (VME). Members design and build special apparatuses for people in need of unique devices to help them live better with their disability. For more information about VME, contact Alice Perrella, Executive Director, Montebello Rehabilitation Hospital, Baltimore, Md.; 410-243-7495; fax, 410-467-3873.

David E. Hamm
Severn, Md.

Effects of EMF

Having read "Today's view of magnetic fields" by Tekla S. Perry [December, pp. 14–23], I suggest that before any concerned readers seriously consider spending thousands, or even hundreds, of dollars on "prudent avoidance" measures, they should read the 300-plus pages of "Health Effects of Low-Frequency Electric and Magnetic Fields."

This report was prepared by an 11-member Oak Ridge Associated Universities Panel for a Federal committee on Interagency Radiation Research and Policy Coordination. Its conclusions and recommendations begin with the sentence: "This review indicates that there is no convincing evidence in the published literature to support the contention that exposure to extremely low-frequency electric and magnetic fields (ELF-EMF) generated by sources such as household appliances, video display terminals, and local power lines are demonstrable health hazards."

The report, dated June 1992, is available from the U.S. Government Printing Office, Superintendent of Documents, Washington, DC 20402. To order a copy, refer to Publication No. 029-000-0044309 and include a check for $25, payable to the Superintendent of Documents.

Lawrence G. Rubin
Newton Centre, Mass.

A reader could look at the "error bars" reported in the article and get the impression that EMF exposure is beginning to look like a real cause of cancer. Yet the same kind of indication may be obtained from a table of random numbers, where there is no real cause for the various trends that can be found.

In other words, if you look for unusual statistics in a wide enough range of places, you are very likely to find occurrences of strictly random clustering somewhere, even though there is no real cause. The countervailing "nothing unusual" or "less than usual" studies tend to be abandoned without publication, since renewals of grants and favorable editorial decisions are not often forthcoming. (Some "less than usual" results were in the *IEEE Spectrum* article, but how many were abandoned without publication?)

If a large number of investigators all set out to find the *same* type of cancer, and if almost all of them had found it to a large degree, with results not discarded, that would have been a different story. But then we would have expected the age-adjusted cancer rates to have gone up steadily in the United States since about 1940, when electricity usage began to grow exponentially. While the occurrences of some types of cancer have gone up, the rates for other types have gone down, and the overall age-adjusted rate in the United States has been amazingly constant over the last half century (see *The New York Times*, March 2, 1982, p. C1).

Daniel Shanefield
Piscataway, N.J.

In his letter "Part of the problem" [December, p. 4], W. G. Brodsky takes the broadcasting industry to task for failing to report on the potential hazards of their RF transmissions. As a consultant to that industry, I can state that Brodsky assumes a level of sophistication by radio programmers that simply does not exist.

To the contrary, I have frequently been embarrassed by client stations that have not only aired such information, but have helped to publicize the views of some of the quacks in the RF field. The typical broadcast programmer has not the slightest idea of how his efforts travel through thin air to reach his audience, and the last thing he would do would be to seek the advice of the station's engineering department in preparing programs on the subject.

If broadcasters are inadequately covering the issue of RF exposure, it is not a plot but just plain old human ineptitude.

Neil M. Smith
Washington, D.C.

Long arm of the law

The implications of "Keeping tabs on criminals" by Joseph Hoshen, Jim Sennott, and Max Winkler [February, pp. 26–32] are fascinating. We all agree that criminals should be controlled, but why stop with criminals? How long will it be before such systems are advocated as ways of keeping track of children?

And to make the transponders as trouble-free (and tamperproof) as possible, why not implant them surgically at birth? It is done with livestock, and the same or similar devices could be used for people. Power is not a problem, because such RF-ID devices can be passive and powered by the interrogating device.

What a brave new world we would have. With widespread use of electronic funds transfer systems (including ATMs), our daily financial transactions can already be tracked as to amount, location, time, and the parties involved. Now, with this capability to track each of us, our dossiers could be updated in real time.

The article mentions methods for sending physical data in one direction and punishments and rewards in the other. Just think of it: no more crime. No more troublemakers. No more dissenters. No need for courts, or prisons, or laws, or privacy, or bills of rights. Just legions of obedient people doing and thinking exactly what they are told by their all-wise leaders.

Peter Cleaveland
Plymouth Meeting, Pa.

Eye on the sky

As director of the National Astronomy and Ionosphere Center at Cornell University, I enjoyed Glenn Zorpette's article "Radio astronomy: new windows on the universe" [February, pp. 18–25]. But in this extensive review, the upgrade of the Arecibo Radio Observatory was unfortunately omitted.

As part of an effort funded jointly by the National Science Foundation and the National Aeronautics and Space Administration (NASA), the Arecibo observatory is undergoing a series of major capability enhancements that will dramatically increase its value to a wide range of disciplines in radio and radar astronomy. The Arecibo upgrade includes a number of components.

One is the Gregorian corrector system, which will allow the extremely large collecting area of the Arecibo antenna to be illuminated with very high efficiency at any frequency from approximately 300 MHz to above 10 GHz. This improvement will provide radio astronomers with the most sensitive signal-receiving system in the world, which will undoubtedly be extremely productive in studying pulsars, external

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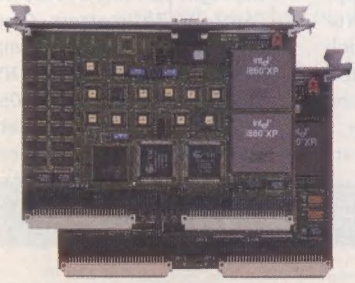
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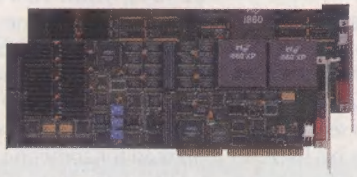
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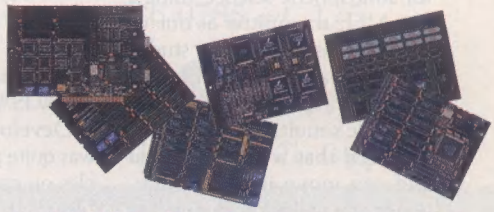
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forum

Continued from p. 6

galaxies, and molecular and atomic gas in the Milky Way.

The Gregorian system will supplement the spherical primary reflector by a two-surface reflective corrector, allowing the use of conventional point-like feed horns. This system will replace the line feeds previously required to illuminate the spherical primary. Line feeds are effective at frequencies up to approximately 2 GHz, but are very limited in bandwidth (50 MHz at most) and exhibit excessive loss at higher frequencies.

A second component of the upgrade is a ground screen, a 50-ft-tall, inclined reflective fence surrounding the 1000-ft-diameter spherical primary reflector. The ground screen terminates spillover radiation on the cold sky, rather than on the 300-K ground, significantly reducing the total system temperatures when the antenna beam is not pointed exactly at the zenith. The screen was completed in August, and the measured reduction in system temperature that it provides is very close to that predicted.

In addition, the 2.38-GHz planetary radar transmitter is having its power doubled to 1 MW. In combination with the increase in sensitivity afforded by the Gregorian corrector system and the ground screen, this will provide an order-of-magnitude improvement in sensitivity for studies of distant objects in the solar system. Extensive, detailed studies of asteroids are only one component of the exciting science that will be enabled by the upgraded Arecibo telescope.

The Gregorian upgrade will also permit enhancements in the observatory's capabilities for atmospheric science, using a 430-MHz transmitter as one of the main instruments for studying earth's atmosphere. Having the beam from the Gregorian available simultaneously with a line feed that will be retained and can move in angle independently will allow dual-beam probing of the atmosphere. This approach also enlarges its capability for determining wind velocities as well as other parameters of the atmosphere.

The upgrade of the telescope itself is being accompanied by development of a series of low-noise receivers, as well as extremely powerful signal-processing electronics.

A customized very large-scale circuit will be the basis of an autocorrelation spectrometer. The chip was developed by the National Astronomy and Ionosphere Center and the NASA Space Electronics Research Laboratory in Albuquerque, N.M., in conjunction with the National Radio Astronomy Observatory and the Naval Research Laboratory. Produced by Hewlett-Packard, it has the highest density of any large-scale non-memory IC yet developed and represents an important partnership between universities and industry on a vital technical forefront area.

Overall, the upgraded Arecibo observatory telescope will represent a major facility for U.S. and non-U.S. astronomers and atmospheric scientists for the foreseeable future. We very much hope that the new capabilities will encourage continuation of the long series of important scientific discoveries carried out at the observatory.

Paul F. Goldsmith
Ithaca, N.Y.

The article on radio astronomy [February, p.18] applies the word *suction* to a process for the acceleration of electrons. Suction can exist only in a pressure field in a fluid, and the concept can only describe the opposite of the application of pressure.The term needed to describe the acceleration of an electron (or other particle) toward a black hole is *gravitational pull* or *acceleration.*

John Firth
firth@hiaras.bia.nrc.ca

Career comments

As chairman of the IEEE-USA's Career Maintenance & Development Committee, I was quite pleased to see the articles on career issues by John A. Hoschette. Career management has always been the individual's responsibility. However, until the 1990s most of us did not have to worry about our careers.

Now the environment is vastly different. Specifically, engineers need to focus on how the skills they have today match their employers' needs. Will the same ones be needed in the future? What others should be developed? Skills and knowledge assessment is a must for unemployed and employed engineers.

Paul J. Kostek
p.kostek@ieee.org

As president of the Society of Women Engineers and a member of the IEEE, I enjoyed reading John A. Hoschette's "A mentor in hand" [February, pp. 56–58] until I reached the section titled "For women, a word of caution."

First, the Society opened its membership to men 20 years ago, in 1975. Second, while we do give members the opportunity to network and learn from one other, it is still virtually impossible for a woman engineer to have several mentors, which Hoschette states "are an absolute necessity." In over 20 years as a student and working engineer, I have made contact with many successful women engineers, very few of whom have had the privilege of working with a female mentor, much less several.

Women in engineering have been rising in the management ranks, but are spread out over the industry. As long as men continue to dominate engineering, women will continue to seek men as mentors. When they do, they will be wise to beware the dangers that are "prone to prevent the course of the mentoring relationship from running smoothly."

Jaclyn A. Spear
Aiken, S.C.

In "The in-house springboard to success" [March, pp. 62–64], John A. Hoschette discusses the manner in which to handle internal promotion policies but fails to address the absurdity of applying for a position that is already earmarked for someone else.

The idea that a company would set a policy that asks candidates to apply for a job they have no hope of getting is ridiculous. The pretense of wanting to hire the most suitable candidate and not the supervisor's favorite demonstrates how poorly the firm is handling its human resources.

I believe in the development of personnel from within an organization to make them suitable for future promotion. I also believe in honesty when employees do not measure up.

Do not condone the use of an underhanded process to give valuable people expectations that have no possibility of being realized. An easy win-win situation for company and employee soon becomes lose-lose when foolish management schemes are revealed.

R. A. Bernard
Richmond, B.C., Canada

Corrections

In "Where buses cannot go" in the February issue, under To Probe Further on p. 45, the fifth line of the second paragraph should have given the year of publication of the *IEEE Computer* issue as 1990.

In the article "Remote sensing" in the March issue, in the first paragraph under "From any viewing angle" on p. 29, the Orthomax ought to have been cited as a product and registered trademark of Vision International, a commercial division of Autometric Inc., of Alexandria, Va. Vision International not only developed but also maintains and markets Orthomax, which is also marketed through Erdas.—*Ed.*

Readers are invited to comment in this department on material previously published in *IEEE Spectrum,* on IEEE policies and operations, and on matters of interest to the profession. Short, concise letters are preferred. The Editor reserves the right to limit debate on controversial matters. Contact: Forum, *IEEE Spectrum,* 345 E. 47th St., New York, NY 10017, U.S.A.; fax, 212-705-7453. The e-mail (Internet) address is n.hantman@ ieee.org. For more information, call 212-705-7305 and ask for the Author's Guide.





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books

Art for computer's sake

BART KOSKO

What is art? Art is what an artist does. Then what is an artist? A type of function. An artist maps experience to symbols. She converts the inputs of life into colors or musical tones or words or dance twists. She may express herself in a shout when she stubs her toe in the dark, but the shout does not come from a set of structured symbols. So most of us would not regard it as art.

In the same way, we tend not to view as art the random walking of a cat on a piano keyboard or the shivering of a dancer who has the flu. The artist must map experience to symbols for the result to count as art. Life is the grist for the artist's symbol mill.

This view of the artist as function reflects what abstract painter Wassily Kandinsky meant when he said that the "inner desire of the artist expresses itself in different ways"—to each his own function. And the function of art changes as the artist's brain adapts to new inputs, as the artist looks for new symbol ways to express himself and for new inputs to excite that expression. Sampling behavior drives creative output. Here the best creative advice comes from behaviorist B. F. Skinner: Vary your stimuli.

The view of art as function in addition opens the door to computer automation. Machine intelligence is a *model-free* form of function approximation. It gives a type of smart black box that maps inputs to outputs. No one guesses at a math model of the throughput process or "plant." The expert holds the new chick to the light and then puts it either in the hen pile or the rooster pile. He has no idea of the equations that define the nonlinear boundary between hens and roosters in some chick pattern space of stunningly high dimension. He does it *by feel* or trained intuition—and so does the artist.

Neural networks can learn some of an artist's intuitions by training on the artist's symbol patterns. Neural nets can better and better approximate the artist's function with more and more training patterns. The same holds true for fuzzy systems that employ neural schemes to tune the fuzzy patterns in their IF-THEN rules.

Both neural and fuzzy systems are universal function-approximators. In theory these approximators can model any system if they use enough neurons or rules and sample enough data. Noise or chaos might vary the rules to a search for new minima of some aesthetic cost function. So we may not need to scratch Beethoven's bones, regene him in *Jurassic Park* style, and train his clone on his old works to get his next 9 or 9000 symphonies. We can just train model-free nets with his old works and thus seed art space with a new set of Beethoven patterns.

Some evidence for this approach already exists. Neural pioneer Teuvo Kohonen of Helsinki University has built a neural musical grammar system that learns the rough patterns of sampled styles—from medieval madrigals to J. S. Bach's two- and three-part inventions to modern jazz and Latin improvisation. Kohonen's neural compositions have often played as background music during the welcoming party of the IEEE international neural conferences. Researchers in Korea and Japan have recently combined chaotic search with neural-fuzzy systems to arrange music in chosen styles. Music remains the sound of math.

Digital Mantras: The Languages of Abstract and Virtual Worlds.
Holtzman, Steven R., MIT Press, Cambridge, Mass., 1994, 460 pp., $29.95



You will find no mention of these systems or of the neural-fuzzy approach of function approximation in Steven Holtzman's new book on computer music, *Digital Mantras: The Languages of Abstract and Virtual Worlds.* The author recasts his thesis work and travels in India into a "book that aims to establish an aesthetic foundation for the use of computers for creative expression in language, music, art, and virtual reality." But Holtzman views his subject from the *symbolic* viewpoint of early 1980s' computer science and "artificial intelligence": thought as a language string. He does not seem aware of the numerical approaches to the same subject, even though in 1991 his publisher MIT Press published the neural-net volume *Music and Connectionism.*

Holtzman sees the digital computer as the final symbol manipulator in a long

line of failed starts and lesser symbol systems. These range from the musical scales of the ancient Greeks and the grammars of ancient Sanskrit scholars to Leibniz's logic schemes and calculators and Kandinsky's visual grammars. It all leads up to the symbol crunching of artificial intelligence: "An assumption of artificial intelligence is that the world can be represented symbolically, that knowledge can be represented in terms of the structure defining how the objects of this symbolic universe relate and interact, and that thinking and intelligence can be described in terms of rules...The computer is essentially a structure manipulator."

That last remark contains the book's main conclusion: the symbolism of computer science goes hand in hand with the structuralism in the formal grammars of Noam Chomsky, the rule-based atonal music of Pierre Boulez, and the pop philosophy of French intellectuals. "To understand is to grasp deep structure," Holtzman says. "Emotion is structure...Structure is meaning...Technology is a tool for investigating the cosmic truths found in structure." And so on. He extends the symbolic world view of the logical positivists of the 1930s to modern painting and music and computer art. What results is a clear account of how artists or machines produce "modern art."

Of course, the trouble with much modern art is that it tastes bad. And the more the artist relies on formal structures like 12-tone rows or color grammars, the worse it tends to taste. We want the artist to create something that we cannot and that comports with our fuzzy notions of beauty. We find that in the works of Shakespeare and Bach and Michelangelo. These artists worked with finely honed intuitions or neural associative memories, not with explicit rules of construction. The worst screenplay uses the same rough rules of drama that Shakespeare used. And the kind of rules Bach could state were for the most part the negative rules of counterpoint: avoid parallel voices in unison or perfect fifths.

The great artists show their artistry by searching out largely unstructured regions of their art space or by bending or breaking the working rules of their art forms. Most of them would find it easier to program a robot to sculpt twisted-bronze "art" pieces for posh shopping malls than to program it to sculpt marble statues in the style of Michelangelo. It is one thing to give a computer rules but quite another to give it intuition.

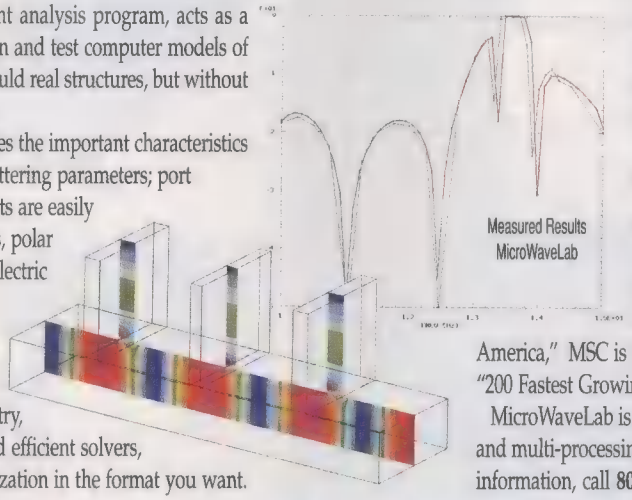
Holtzman finds some support for his art-as-structure thesis in the beauty of fractals. A simple repeated equation or rule can grow nonlinear boundaries in the plane that delight the eye. And random-dot stereograms now make for small best-selling books of neat things to look at or taxing textures to put on gift cards or place mats. But the beauty of fractals and stereograms came as an afterthought or an after-perception. Scientists first used them as a means to explain things and not as artistic ends in themselves.

Holtzman points to less compelling data from computer music or the atonal serial music that composers write more by head than heart. "Electronic sounds were completely alien thirty years ago," he writes. "Today they are heard everywhere. Even scratching sounds and noise

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are now part of the accepted sound world of rap music and MTV."

That may be so, and rap music may be fun and full of social punch. But who thinks rap music is beautiful? Friedrich von Schelling said last century that "architecture is frozen music." One hates to picture the gray bombed-out structures that would come from "freezing" rap or atonal serial music.

The book comes with a compact disk of samples of Holtzman's own music. These are short solo works and atonal in the bargain. The liner notes tell of the rule-based grammars and the stochastic transition matrices that led to the works. His "Solo for Harp" shows how the medium can be much of the message: on a harp even pseudo-random atonal notes sound pleasant. Some of the pure computer "structures" sound a lot like what one hears on a walk through a video arcade.

Digital Mantras succeeds in its telling of musical and structuralist history but fails in its synthesis of the two. The reader will learn a great deal about how music and language have evolved in all cultures and how computers and engineering may accelerate their evolution in the future. In this sense the book is a noble effort. Art is too fine a thing to leave in the hands of the humanities.

Bart Kosko is director of the University of Southern California's (USC's) Signal and Image Processing Institute and an associate professor of electrical engineering. He wrote the popular book and international best-seller *Fuzzy Thinking* as well as the Prentice Hall texts *Neural Networks and Fuzzy Systems, Neural Networks for Signal Processing,* and the new *Fuzzy Engineering,* to appear this fall. He won a full scholarship in music composition to USC when he was 17 years old and finished his first symphony when he was 18.

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Digital Video: Concepts and Applications Across Industries. Ed. *Rzeszewski, Theodore S.*, IEEE Press, Piscataway, N.J., 1995, 591 pp., $69.95 (list price), $56.00 (member price).

The Collapse of Chaos: Discovering Simplicity in a Complex World. *Cohen, Jack,* and *Stewart, Ian,* Penguin Books, New York, 1994, 495 pp., $13.95.

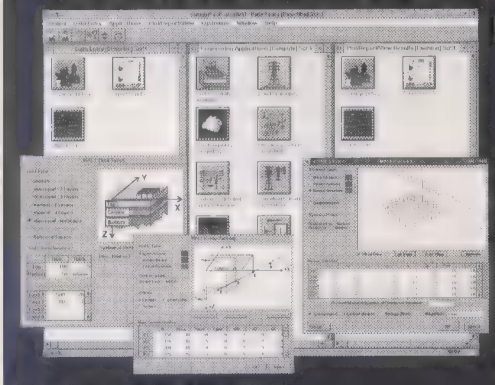
Energy Effective Industrial Illuminating Systems. *Chen, Kao,* Fairmont Press, Lilburn, Ga., 1994, 180 pp., $69.

The Small Business Computer Guide. *Beckman, Joseph S.*, Digital Press/Butterworth-Heinemann, Woburn, Mass., 1995, 374 pp., $29.95.

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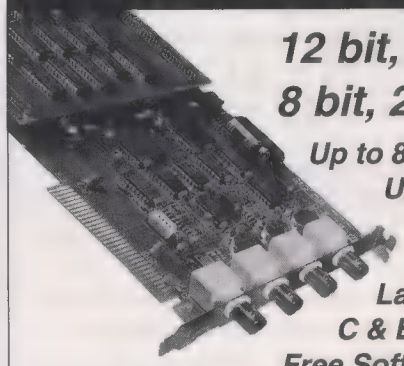
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Microwave and Millimeter-Wave Monolithic Circuits Symposium (ED); May 15–16; Orange County Convention Center, Orlando, Fla.; Val Peterson, Hewlett-Packard Co., 1412 Fountaingrove Parkway, Building 1, Santa Rosa, CA 95403; 707-577-2304; fax, 707-577-4090.

Real-Time Technology and Applications Symposium (C); May 15–17; Bismark Hotel, Chicago; Theodore P. Baker, Department of Computer Science, Florida State University, Tallahassee, FL 32306–4019; 904-644-2296; fax, 904-644-0058; e-mail, baker@cs. fau.edu.

International Conference on Multimedia Computing and Systems (C); May 15–18; Sheraton Premiere Hotel, Vienna, Va.; Arun Sood, Department of Computer Science, George Mason University, 4400 University Dr., Room 430, Fairfax, VA 22030–4444; 703-993-1524; fax, 703-993-3729; e-mail, ICMCS95@cs.gmu.edu.

Forum on Research and Technology Advances in Digital Libraries (C); May 15–19; Digital Libraries, Washington, D.C.; Milton Halen, Goddard Space Flight Center, NASA, Greenbelt, MD 20771; 301-266-8834; fax, 301-286-1777; e-mail, mhalen@gssemail.nasa.gov.

International Microwave Symposium—MTT '95 (MTT); May 15–19; Orange

178, Building 965, Thompson Place, Box 3453, Sunnyvale, CA 94088; 408-749-4213; fax, 408-749-5585.

National Telesystems Conference—NTC '95 (AES, MTT, Orlando Section); May 17–19; Orange County Convention Center, Orlando, Fla.; NTC '95, LRW Associates, 1218 Balfour Dr., Arnold, MD 21012; 410-647-1591; fax, 410-647-5136.

Pacific Rim Conference on Communications, Computers, Visualization and Signal Processing (Victoria C); May 17–19; Victoria Conference Centre, B.C., Canada; Mary O'Rourke, Conference Services, University of Victoria, Victoria, BC V8W 2Y2, Canada; 604-721-84656.

Third ACM Symposium on Solid Modeling and Applications (C); May 17–19; Red Lion Hotel, Salt Lake City, Utah; Mike Pratt, National Institute of Science and Technology, Building 220, Rm. A127, Gaithersburg, MD 20899–0001; 301-975-3951; fax, 301-258-9749; e-mail, pratt@cme. nist.gov.

Wireless Personal Communications: A Telecommunications Revolution (COM); May 18; United Engineering Center, New York City; Jim Barbera, 333 Seventh Ave., New York 10001; 212-594-7688; fax, 212-465-8877; e-mail, j.p.barbera@ieee.org.

Ninth Conference on Real-Time Computer Applications in Nuclear, Particle and Plasma Physics (NPS);

45th Electronic Components and Technology Conference—ECTC '95 (CMPT); May 22–24; Caesars Palace, Las Vegas, Nev.; Peter J. Walsh, Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, DC 20006; 202-457-4932.

International Workshop on Applications of Neural Networks to Telecommunications—Iwannt '95 (COM); May 22–24; Royal Swedish Academy of Engineering Science, Stockholm, Sweden; Joshua Alspector, Bellcore, MRE 2P-396, 445 South Street, Morristown, NJ 07960; 201-829-4929; fax, 201-829-5888; e-mail, josh@bellcore.com.

Fifth Dual-Use Technologies and Applications Conference (Mohawk Valley Section); May 22–25; State University of New York at Utica/Rome; Dawn Farry, Suny IOT at Utica Rome, Box 3050, College Relations Office, Utica, NY 13504–3050; 315-792-7113; fax, 315-792-7222; e-mail, dawn_farry@barney.info.sunyit.edu.

International Conference: Industrial Automation and Control: Emerging Technology Applications (IA); May 22–27; National Taipei Institute of Technology, Taiwan; Paul I-Hai Lin, IU-Purdue University, 2101 Coliseum Blvd. E., Fort Wayne, IN 46805;

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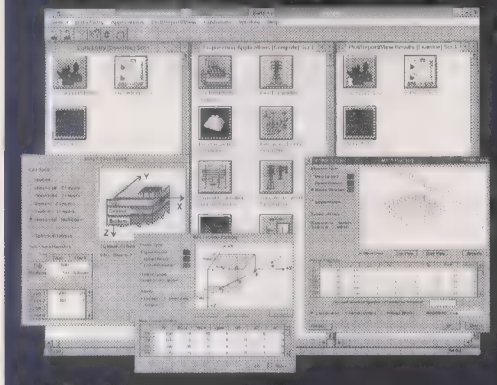
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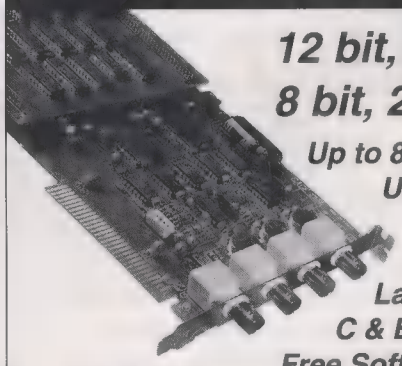
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Workshop on Interconnections Within High Speed Digital Systems (COM, LEO); May 14–17; Picacho Plaza Hotel, Santa Fe, N.M.; Samantha Phillips, IEEE/LEOS, Box 1331, Piscataway, NJ 08855–1331; 908-562-3894; fax, 908-562-8434; e-mail, s.phillips@ieee.org.

Microwave and Millimeter-Wave Monolithic Circuits Symposium (ED); May 15–16; Orange County Convention Center, Orlando, Fla.; Val Peterson, Hewlett-Packard Co., 1412 Fountaingrove Parkway, Building 1, Santa Rosa, CA 95403; 707-577-2304; fax, 707-577-4090.

Real-Time Technology and Applications Symposium (C); May 15–17; Bismark Hotel, Chicago; Theodore P. Baker, Department of Computer Science, Florida State University, Tallahassee, FL 32306–4019; 904-644-2296; fax, 904-644-0058; e-mail, baker@cs. fau.edu.

International Conference on Multimedia Computing and Systems (C); May 15–18; Sheraton Premiere Hotel, Vienna, Va.; Arun Sood, Department of Computer Science, George Mason University, 4400 University Dr., Room 430, Fairfax, VA 22030–4444; 703-993-1524; fax, 703-993-3729; e-mail, ICMCS95@cs.gmu.edu.

Forum on Research and Technology Advances in Digital Libraries (C); May 15–19; Digital Libraries, Washington, D.C.; Milton Halen, Goddard Space Flight Center, NASA, Greenbelt, MD 20771; 301-266-8834; fax, 301-286-1777; e-mail, mhalen@gssemail.nasa.gov.

International Microwave Symposium—MTT '95 (MTT); May 15–19; Orange County Convention Center, Orlando, Fla.; G. K. Huddleston, 506 Lisa Lane, Maitland, FL 32751; 407-339-0336; fax, 407-356-7201.

University/Government/Industry Microelectronics Symposium (ED); May 16–18; J. J. Pickle Research Center, University of Texas, Austin; Mahboob Khan, Advanced Micro Devices, MS 178, Building 965, Thompson Place, Box 3453, Sunnyvale, CA 94088; 408-749-4213; fax, 408-749-5585.

National Telesystems Conference—NTC '95 (AES, MTT, Orlando Section); May 17–19; Orange County Convention Center, Orlando, Fla.; NTC '95, LRW Associates, 1218 Balfour Dr., Arnold, MD 21012; 410-647-1591; fax, 410-647-5136.

Pacific Rim Conference on Communications, Computers, Visualization and Signal Processing (Victoria C); May 17–19; Victoria Conference Centre, B.C., Canada; Mary O'Rourke, Conference Services, University of Victoria, Victoria, BC V8W 2Y2, Canada; 604-721-84656.

Third ACM Symposium on Solid Modeling and Applications (C); May 17–19; Red Lion Hotel, Salt Lake City, Utah; Mike Pratt, National Institute of Science and Technology, Building 220, Rm. A127, Gaithersburg, MD 20899–0001; 301-975-3951; fax, 301-258-9749; e-mail, pratt@cme. nist.gov.

Wireless Personal Communications: A Telecommunications Revolution (COM); May 18; United Engineering Center, New York City; Jim Barbera, 333 Seventh Ave., New York 10001; 212-594-7688; fax, 212-465-8877; e-mail, j.p.barbera@ieee.org.

Ninth Conference on Real-Time Computer Applications in Nuclear, Particle and Plasma Physics (NPS); May 21–25; Kellogg Center, East Lansing, Mich.; Ron Fox, NSCL, Michigan State University, East Lansing, MI 48824–1321; 517-353-1678; fax, 517-353-5967; e-mail, fox@rscl.mscl.mcu. edu.

Lasers and Electro-Optics and Quantum Electronics and Laser Science Conference—CLEO/QELS (LEOS); May 21–26; Baltimore Convention Center, Maryland; IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855–1331; 908-562-3893; fax, 908-562-8434.

21st Annual Northeast Bioengineering Conference (EMB); May 22–23; College of the Atlantic, Bar Harbor, Me.; Seth Wolpert, 5708 Barrows Hall, University of Maine, Orono, ME 04469–5708; 207-581-2234; fax, 207-581-2220; e-mail, wolpcit@maine.maine.edu.

45th Electronic Components and Technology Conference—ECTC '95 (CMPT); May 22–24; Caesars Palace, Las Vegas, Nev.; Peter J. Walsh, Electronic Industries Association, 2001 Pennsylvania Ave., N.W., Washington, DC 20006; 202-457-4932.

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Fifth Dual-Use Technologies and Applications Conference (Mohawk Valley Section); May 22–25; State University of New York at Utica/Rome; Dawn Farry, Suny IOT at Utica Rome, Box 3050, College Relations Office, Utica, NY 13504–3050; 315-792-7113; fax, 315-792-7222; e-mail, dawn_farry@barney.info.sunyit.edu.

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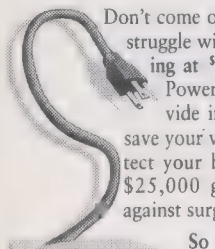
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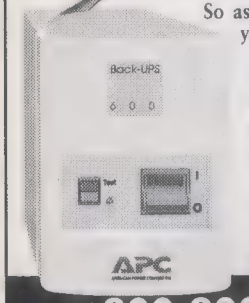
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International Conference on Robotics and Automation (RA); May 22–27; Nagoya Congress Center, Nagoya, Japan; Toshio Fukuda, Department of Mechano-Informatics and Systems, Nagoya University, Furo-cho, Chikusa-Ku, Nagoya 464–01, Japan; (81+52) 781 5111, ext. 4478.

International Symposium on Power Semiconductor Devices and Integrated Circuits (ED); May 23–25; Yokohama Convention Center, Japan; Toshiaki Yachi, Nippon Telegraph and Telephone Corp., NTT Interdisciplinary Research Laboratory, 9–11, Midori-Cho, Musashino-shi, Tokyo 180, Japan; (81+422) 59 3129; fax, (81+422) 59 2172.

International Symposium on Intelligence in Neural and Biological Systems (C); May 29–31; Hyatt Hotel at Dulles Airport, Herndon, Va.; Nikolaos G. Bourbakis, Department of Electrical Engineering, Binghamton University (SUNY), Binghamton, NY 13902; 607-777-2165; fax, 607-777-4822; e-mail, bourbaki@bingsuns.cc.binghamton.edu.

International Symposium on Electron, Ion and Photon Beams (ED); May 30–June 2; Scottsdale Conference Resort, Arizona; John N. Randall, Texas Instruments Inc., 13588 N. Central Expressway, MS 134, Dallas, TX 75243; 214-995-2723; fax, 214-995-2836.

Fifth Symposium on Wireless Personal Communications (VT); May 31–June 2; Donaldson Brown Hotel and Conference Center, Blacksburg, Va.; Jack Lilly, Virginia Polytechnic Institute and State University, Blacksburg, VA 24061–0104; 703-231-4849; fax, 703-231-3746; e-mail, jacklily@vtvm1.cc.vt.edu.

International Frequency Control Symposium (UFFC); May 31–June 2; Fairmont Hotel, San Francisco, Calif.; Michael R. Mirarchi, Synergistic Management, 3100 Rte.138, Wall Township, NJ 07719; 908-280-2024; fax, 908-681-9314.

International Symposium on VLSI Technology, Systems and Applications (C, ED, et al.); May 31–June 2; Hyatt Hotel, Taipei, Taiwan; Genda J. Hu, Cypress Semiconductor, MS/1–1, 3901 N. First St., San Jose, CA 95134; 408-943-4861; fax, 408-943-2118.

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Holm Conference on Electrical Contacts (CPMT); June 4–11; Radisson Governeurs Hotel, Montreal; Holm Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, NJ 8855–1331; 908-562-3895; fax, 908-562-1571; e-mail, e.hager@ieee.org.

37th Cement Industry Technical Conference (IA); June 5–8; Caribe Hilton Resort and Casino, San Juan, P.R.; Jose A. Alustiza, Puerto Rican Cement Co., Box 364487, San Juan, PR 00936–4487; 809-783-3000; fax, 809-781-8850.

22nd International Conference on Plasma Sciences—Icops (NPS); June 5–8; University of Wisconsin, Madison; Maureen Sundell, The Wisconsin Center, 702 Langdon St., Madison, WI 53706; 608-262-5514; fax, 608-262-8516.

Eighth International Conference on Industrial and Engineering Applications of Artificial Intelligence and Expert Systems (C); June 5–9; Hilton on the Park, Melbourne, Australia; Moonis Ali, Department of CS, Southwest Texas State University, San Marcos, TX 78666–4616; 512-245-3409; fax, 512-245-8750; e-mail, ma04@academia.swt.edu.

Symposium on VLSI Technology (ED); June 6–8; Kyoto Grand Hotel, Japan; Hiroyoshi Komiya, ULSI Laboratories, Mitsubishi Electric, 4–1 Mizuhara, Itam-ishi, Hyogo 664, Japan; (81+727) 82 5131; fax, (81+727) 80 2685.

International Conference on Consumer Electronics—ICCE (CE); June 7–9; Westin Hotel O'Hare, Rosemont, Ill.; Diane D. Williams, 67 Rasberry Patch Dr., Rochester, NY 14612–2868; 716-392-3862; fax, 716-392-4397.

Conference on Insulating Films on Semiconductors (ED); June 7–10; Grand Hotel de Paris, Villard-de-Lans, Grenoble, France; Sorin Cristoloveanu, LPCS, Enserg, BP 257, 23, Rue Des Martyrs, 38016 Grenoble, Cedex 1, France; (33+76) 85 60 40; fax, (33+76) 85 60 70.



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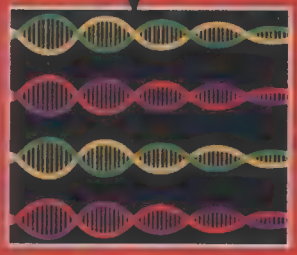
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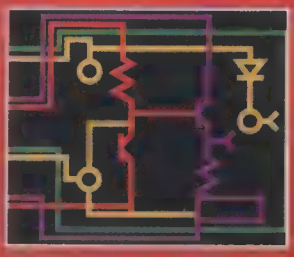
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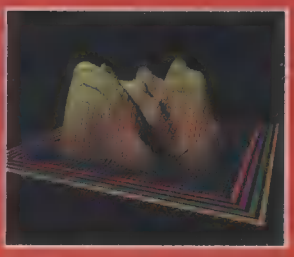
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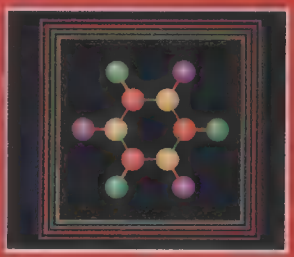
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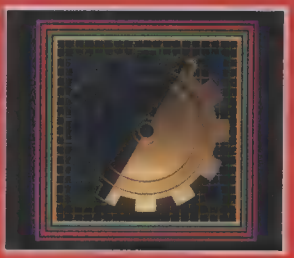
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First International Conference on Multiagent Systems—Icmas '95 (C); June 12–14; San Francisco Hilton and Towers; Victor Lesser, Computer and Information Science Department, University of Massachusetts, Amherst, MA 01003; 413-545-1322; e-mail, lesser@cs.umass.edu.

Workshop on Higher-Order Statistics (SP); June 12–14; Parador de Aiguablava, Girona, Spain; Javier R. Fonollosa, Department of Signal Theory and Communications, Universitat Politécnica de Catalunya, Apartado 30.002, 08071 Barcelona, Spain; (34+3) 401 7052; fax, (34+3) 401 6447; e-mail, fono@tsc.upc.es.

Power Electronics Specialist Conference—PESC '95 (PEL); June 12–15; Swissotel, Atlanta, Ga.; Hans B. Puttgen, School of Electrical and Computer Engineering, Georgia Institute of Technology, Atlanta, GA 30332–0250; 404-894-2927; fax, 404-894-2997.

Intensive Course on Electrical Contacts (CPMT); June 12–16; Holiday Inn Chicago; Holm Conference Registrar, IEEE Technical Activities, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855–1331; 908-562-3870; fax, 908-981-1769.

Pulp and Paper Industry Conference (IA, Vancouver); June 12–16; Westin Bayshore, Vancouver, B.C., Canada; Philip Fransen, Fransen Engineering Ltd., 210–3031 Viking Way, Richmond, BC V6V 1W1, Canada; 604-270-7728; fax, 604-270-6252.

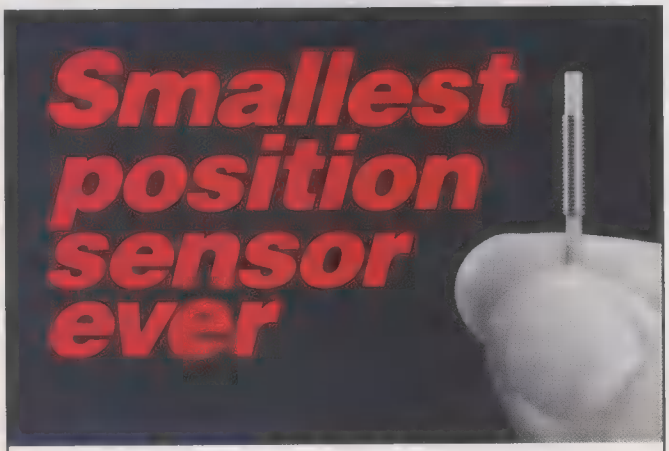
32nd Design Automation Conference (CAS); June 12–16; Moscone Center, San Francisco; MP Associates Inc., 5305 Spine Rd., Suite A, Boulder, CO 80301; 303-530-4333; fax, 303-530-4334; e-mail, mpa@dac.com.

Workshop on Physics-Based Modeling in Computer Vision (C); June 18–19; Massachusetts Institute of Technology, Cambridge; Dimitri Metaxas, Department CIS, University of Pennsylvania, 206 South 33rd St., Philadelphia, PA 19104–6389; 215-898-0945; fax, 215-898-0587.

International Conference on Communications (COM); June 18–21; Seattle Sheraton Hotel and Towers, Washington; Michael Lupton, US West Communications, 1005 17th St., Denver, CO 80202; 303-896-7657; fax, 303-896-8481.

Stockholm Power Tech (PE); June 18–22; Royal Institute of Technology, Stockholm, Sweden; Roland Eriksson, Department of Electric Power Engineering, Royal Institute of Technology, S-100 44 Stockholm, Sweden; (46+8) 790 7988; fax, (46+8) 205 268; e-mail, stockholm95@ekc.kth.se.

International Symposium and USNC/URSI Radio Science Meeting (AP); June 18–23; Newport Beach Marriott Hotel and Tennis Club, California; William Imbriale, Jet Propulsion



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Device Research Conference (ED); June 19–21; University of Virginia, Charlottesville; Umesh K. Mishra, Department of Electrical and Computer Engineering, University of California, Santa Barbara, CA 93106; 805-893-3586; fax, 805-893-2149.

Digital Cross Connect Systems Workshop VI (COM); June 19–22; Banff Park Lodge, Banff, Alta., Canada; Richard Hamley, Stentor Resource Centre Inc., Room 500, 160 Eigin St., Ottawa, ON, K1G 3J4, Canada; 613-781-7969; fax, 613-563-7411.

Fifth International Conference on Computer Vision (C); June 20–23; Massachusetts Institute of Technology, Cambridge; Eric Grimson, MIT AI Laboratory, 545 Technology Square, Cambridge, MA 02139; 617-253-5346; fax, 617-258-6287; e-mail, welg@ai.mit.edu.

American Control Conference—ACC '95 (CS); June 21–23; Westin Hotel, Seattle, Wash.; Glen Masada, Department of Mechanical Engineering, University of Texas, Austin, TX 78712; 512-471-3061; fax, 512-471-7682.

Electro International (Region 1); June 21–23; Hynes Convention Center, Boston; Registration Office, 13760 Noel Rd., Suite 500, Dallas, TX 75240–4332; Kathryn Piersall, 214-419-7969; fax, 214-419-7915; or Paul Baudisch, 617-444-5543.

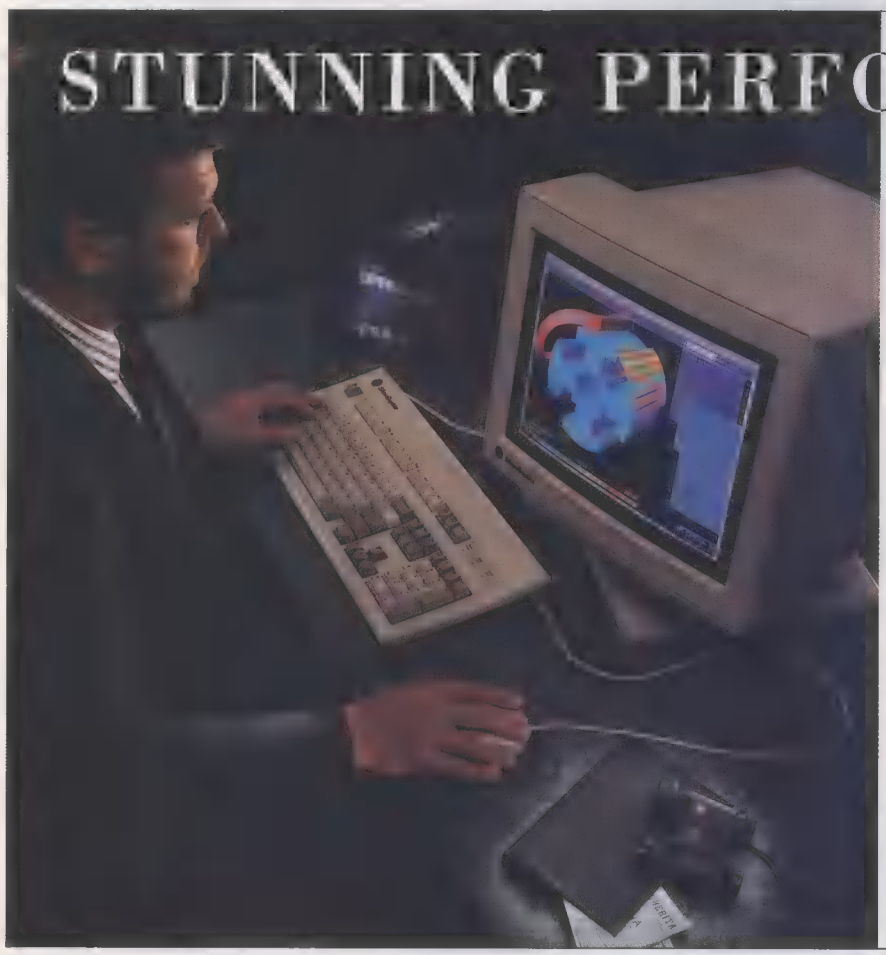
Seventh International Conference on Software Engineering and Knowledge Engineering (C); June 22–24; Holiday Inn Crowne Plaza, Rockville, Md.; Victor R. Basili, University of Maryland, Department of Computer Science, A. V. Williams Building, Room 4111, College Park, MD 20742; 301-405-6228; e-mail, basili@tame,cs.umd.edu.

Transducers—International Solid-State Sensors and Actuators Conference (ED); June 25–29; City Conference Center, Stockholm, Sweden; Beril Hok, Hok Instrument AB, Flottiljgatan 55, S-721 31 Vasteras, Sweden; (46+21) 80 00 99; fax, (46+21) 80 10 09.

Tenth Conference on Computer Assurance (AES); June 26–30; National Institute of Standards and Technology, Gaithersburg, Md.; Bonnie Danner, TRW Systems Division, One Federal Systems Park Drive, Fairfax, VA 22032–4417; 703-876-4383; fax, 703-876-4304.

Symposium on Computers and Communications (C, COM); June 27–29; Hotel in Montazah, Alexandria, Egypt; Mastafa Hasham Sherif, AT&T Bell Laboratories, Room 3G-607, 101 Crawfords Corner Rd., Holmdel, NJ 07733; 908-949-0439; fax, 908-949-7575; e-mail, mhs@hogpd.att.com.

25th International Symposium on Fault-Tolerant Computing (C); June 27–30; Doubletree Hotel, Pasadena, Calif.; John A. Rohr, Jet Propulsion Laboratories, MST-1704, Pasadena, CA 91109–8099; 818-354-4096; e-mail, john.a.rohr@jpl.nasa.gov.



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Global Engineering Management: Emerging Trends in Asia Pacific (EM, Singapore EM Chapter); June 28–30; Convention Center, Singapore; Gurdeep S. Hura, Nanyang Technological University, School of Applied Science/ Computer Technology, Nanyang Avenue, Singapore 2263; (65) 799 1271; fax, (65) 792 6559; e-mail, ashura@ntuvax.ntu.ac.sg or g.hura@ieee.org.

International Engineering Management Conference—EM '95 (EM, Singapore/EM Chapter); June 28–30; Pan Pacific Hotel, Singapore; Conference Secretariat, Conference & Travel Management Associates Pte. Ltd., 425A Race Course Rd., 0821, Singapore; (65) 299 8992; fax, (65) 299 8983.

july

Hong Kong Electron Devices Meeting (ED); July 1; University of Hong Kong; Peter P.T. Lai, Hong Kong University, Clear Water Bay, Kowloon, Hong Kong; (852) 2859 2691; fax, (852) 2559 8738.

Magnetic Recording Conference (MAG); July 10–12; Carnegie Mellon University, Pittsburgh; Mardi Geredes, IIST, Santa Clara University, Santa Clara, CA 95053; 408-554-5478; fax, 408-554-5474.

Fifth International Conference on Conduction and Breakdown in Solid Dielectrics (DEI); July 10–13; University of Leicester, England; John Fothergill, Department of Engineering, Leicester University, Leicester, LEI 7RH, England; (44+533) 522 569; fax, (44+533) 522 619 or 522 525.

International Geoscience and Remote Sensing Symposium (GRS); July 10–14; Congress Centre, Florence, Italy; Paolo Pampaloni, IROE-CNR, via Panciatichi 64, 50127 Firenze, Italy; (39+55) 423 51; fax, (39+55) 410 893.

International Symposium on Industrial Electronics—ISIE '95 (IE); July 10–14; Intercontinental Hotel, Athens, Greece; E. Micheli-Tzanakou, Department of Biomedical Engineering, Rutgers University, Box 909, Piscataway, NJ 08855–0909; 908-932-2037.

Seventh Brazilian Workshop on Semiconductor Physics (Rio Section); July 16–21; Catholic University of Rio de Janeiro, Brazil; P. L. Souza, Cetuc-Puc-Rio, Rua Marques de São Vicente 225, CEP 22453, Rio de Janeiro, Brazil; (55+21) 239 7425; fax, (55+21) 294 5748; e-mail, semic95@cetuc.puc-rio.br.

Radiation Effects Data Workshop (NPS); July 17; Holiday Inn Madison West, Middleton, Wis.; Dale G. Platteter, Naval Surface Warfare Center, Code 605, Building 2088, 300 Highway 361, Crane, IN 47522–5001; 812-854-1808; fax, 812-854-3806.

Nuclear and Space Radiation Effects Conference—NSREC (NPS); July 17–21; Holiday Inn Madison West, Madison, Wis.; John J. Silver, UTMC, 1575 Garden of Gods Rd., Colorado Springs, CO 80907; 719-594-8474; fax, 719-594-8187.

16th International Congress on Instrumentation in Aerospace Simulation Facilities—ICIASF '95 (AES); July 18–21; Hope Hotel and Conference Center, Wright-Patterson

Continued on p. 70E2

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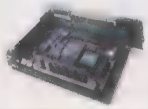
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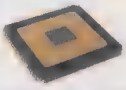
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washington watch

Cuts foreseen for engineering projects

Engineering and science, although "a very high priority of this nation," can expect cuts in direct Federal support, House Science Committee chairman Robert Walker (R-Pa.) told an American Association of Engineering Societies symposium in March. Research support has to be viewed in the context of a US $6 trillion national economy, he said, rather than of a $1.5 trillion Federal budget. By marshaling forces within the entire economy, the Government could use regulations and tax policies as alternatives to boost R&D investments, according to the science committee chair.



Walker said he approves of giving small companies precompetitive technology grants that generically help a broad industry. But, he also told the audience, the Advanced Technology Program (ATP) of the National Institute of Standards and Technology has become a form of corporate welfare. "If you look down the ATP list, it looks like the Fortune 500," he said.

Under Secretary of Commerce Mary Good said the "rumor is not correct" that the ATP will be killed. True, the House voted to reduce ATP's 1995 funding of $431 million by $107 million, while the Senate wanted to rescind $32 million. (The houses later reached a $90 million compromise.) Nevertheless, she declared, "Neither of those numbers augurs a dead program."

Big companies, Good noted, sponsor the bulk of R&D and have the resources to turn the precompetitive, cost-shared ATP projects into products. Small companies often collaborate on those projects, she added. Of 177 ATP awards since 1990, 88 went to small businesses or to joint ventures led by small businesses.

Good said that the ATP should clearly not be allowed to grow indefinitely into a mini-National Science Foundation. But, at a $700 million annual level, she believes, it could be a key national program with five strategic programs renewed each year.

U.S. technology lead shrinks

Although the United States remains equal or superior to Japan and Europe in 27 technology areas deemed critical to national and economic security, its lead in many of these areas is slipping, according to the National Critical Technologies Report, which was released on March 21 to President Bill Clinton. The report was prepared under the direction of the White House Office of Science and Technology Policy with assistance from Rand Corp.'s Critical Technologies Institute.

U.S. research is on a par with that in Japan in six areas, including nanofabrication, sensors, and pollution control. In 10 areas, the United States has a substantial lead, and in 11 a slight lead. But the trend of the last four years indicates Japan's rate of advance is outpacing that of U.S. research in communications, materials, avionics and seven other areas.

The United States has a substantial lead over Europe in only one area (human-machine interfaces), a slight lead in 18 areas, and parity in seven. (One area was not considered a benchmark for Europe.) In the past four years, Europe has narrowed the gap in four research areas.

Copies of the report are available from Linda Tanner of Rand Corp. at 202-296-5000, ext. 5692.

Engineers net Capitol jobs

The level of Capitol debate may be raised this year by four engineers recently selected for IEEE-U.S. Activities Government fellowships. One will work in the Department of Commerce, while three will serve as congressional fellows.

James C. Dennison, who will serve as an executive fellow (supported in part by the Alfred P. Sloan Foundation), is to work with Commerce Under Secretary Mary Good. Dennison is vice president for engineering of Information Optics Corp., Issaquah, Wash.

Robert Duane Shelton will serve Representative Lloyd Doggett (D-Texas), a member of the House Science Committee and its subcommittee on basic research. Currently, he is director of the International Technology Research Institute at Loyola College in Baltimore, Md.

Donald M. Wiberg joins the office of Senator Tom Harkin (D-Iowa), where he hopes to help in shaping energy and defense policy. He is a professor in the electrical engineering department at the University of California at Los Angeles.

Paul B. Crilly, a 1994 congressional fellow, has had his tenure extended for an extra year by IEEE-USA at the request of Representative Dana Rohrabacher (R-Calif.), the newly appointed chairman of the House Science subcommittee on energy and the environment. Crilly is associate professor of electrical engineering at the University of Tennessee in Knoxville.

More information on the program is available from Chris Brantley of IEEE-USA at 202-785-0017 or c.brantley@ieee.org.

Reorganizing the bureaucracy

Republicans and Democrats are dueling with each other over the revamping of Government. In March, to supplement a $20 billion savings plan announced in December, President Clinton outlined $13 billion in cuts at NASA, the Department of Interior, the Small Business Administration, and the Federal Emergency Management Agency.

Republicans are considering scrapping departments. Those mentioned include Commerce, Energy, Transportation, and Housing and Urban Development.

All of this may make it easier to create a new Department of Science, an old idea revived by House Science Committee chairman Robert Walker. This cabinet-level entity would combine parts of the disbanded Commerce and Energy departments with the National Science Foundation, the Environmental Protection Agency, and NASA. (Notable exclusions would be research at the Defense Department and National Institutes of Health.) Walker hopes such a department would help rationalize spending.

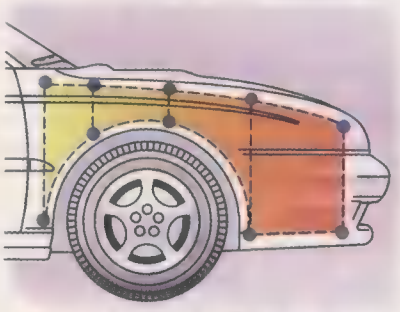
Last gasp for OTA?

The Congressional Office of Technology Assessment "probably will not survive the next cut for next year," predicted House Science Committee chairman Robert Walker at a briefing of District of Columbia science writers. Although the agency conducts decent studies, it is not in sync with the legislative cycle, he said.

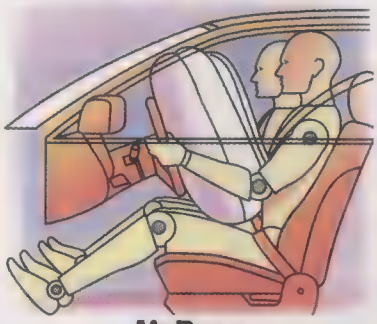
OTA director Roger Herdman admitted the elimination prospect is "serious." The $22-million-a-year agency with 185 staffers has volunteered a 20 percent cut, and has promised to speed its delivery of peer-reviewed reports. It has also prepared for the Senate a study of OTA's impact over the last three years. "We've done some good things," Herdman said. Possible future study topics include risk assessment, space launches, and drug regulation. [See "The office of technology assessment: an endangered species worth saving," *IEEE Spectrum*, February 1995, pp. 13–14.]

JOHN A. ADAM, *Washington Editor*

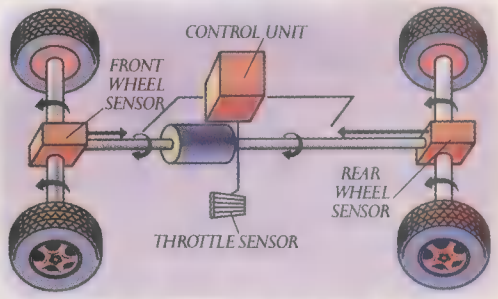
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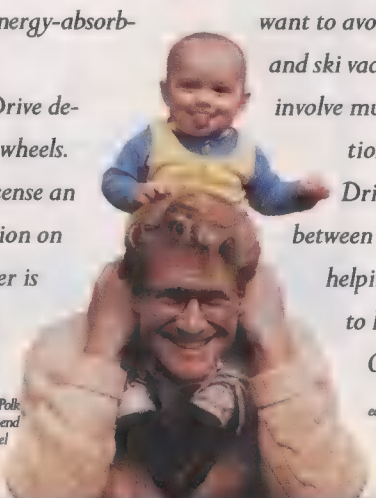
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recent books

The Product Development Challenge: Competing Through Speed, Quality and Creativity. Ed. *Clark, Kim B.*, and *Wheelwright, Steven C.*, Harvard Business School Press, Boston, 1994, 448 pp., $32.50.

AS/400 System Administration Guide. *Gamble, Jesse*, and *Merrow, Bill*, McGraw-Hill, New York, 1995, 402 pp., $45.

CDMA: Principles of Spread Spectrum Communication. *Viterbi, Andrew J.*, Addison-Wesley, New York, 1995, 272 pp., $59.25.

Manufacturing Renaissance. *Pisano, Gary P.*, and *Hayes, Robert H.*, Harvard Business School Press, Boston, 1995, 384 pp., $29.95.

Object-Oriented Client/Server Application Development: Using Object-PAL and C++. *Ayer, Steve*, McGraw-Hill, New York, 1995, 206 pp., $40.

Emerging Patterns of Innovation: Sources of Japan's Technological Edge. *Kodama, Fumio*, Harvard University School Press, Boston, 1995, 320 pp., $35.

Computational Learning Theory and Natural Learning Systems. Eds. *Hanson, Stephen Jose, et al.*, MIT Press, Cambridge, Mass., 1994, 449 pp., $42.50.

From EDI to Electronic Commerce: A Business Initiative. *Sokol, Phyllis K.*, McGraw-Hill, New York, 1995, 305 pp., $40.

Stochastic Processes, Estimation, and Control: The Entropy Approach. *Saridis, George N.*, John Wiley & Sons, New York, 1995, 230 pp., $69.95.

Introduction to Wave Scattering Localization, and Mesoscopic Phenomena. *Sheng, Ping*, Academic Press, New York, 1995, 339 pp., $69.95.

Personal Computer Interfaces: Macs to Pentiums. *Hordeski, Michael*, McGraw-Hill, New York, 1995, 379 pp., $55 (hardcover), $39.95 (paperback).

Internetworking: Designing the Right Architectures. *Smythe, Colin*, Addison-Wesley, New York, 1995, 473 pp., $37.75.

Fundamentals of Optical Fibers. *Buck, John A.*, John Wiley & Sons, New York, 1995, 264 pp., $59.95.

Electric Power System Protection and Coordination: A Design Handbook for Overcurrent Protection. *Anthony, Michael A.*, McGraw-Hill, New York, 1995, 395 pp., $50.

Operational Amplifier Circuits: Analysis and Design. *Nelson, John C.C.*, Butterworth-Heinemann, Boston, 1995, 138 pp., $22.95.

Rendezvous with ADA 95, 2nd edition. *Naiditch, David J.*, John Wiley & Sons, New York, 1995, 598 pp., $44.95.

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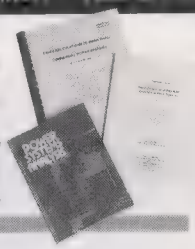
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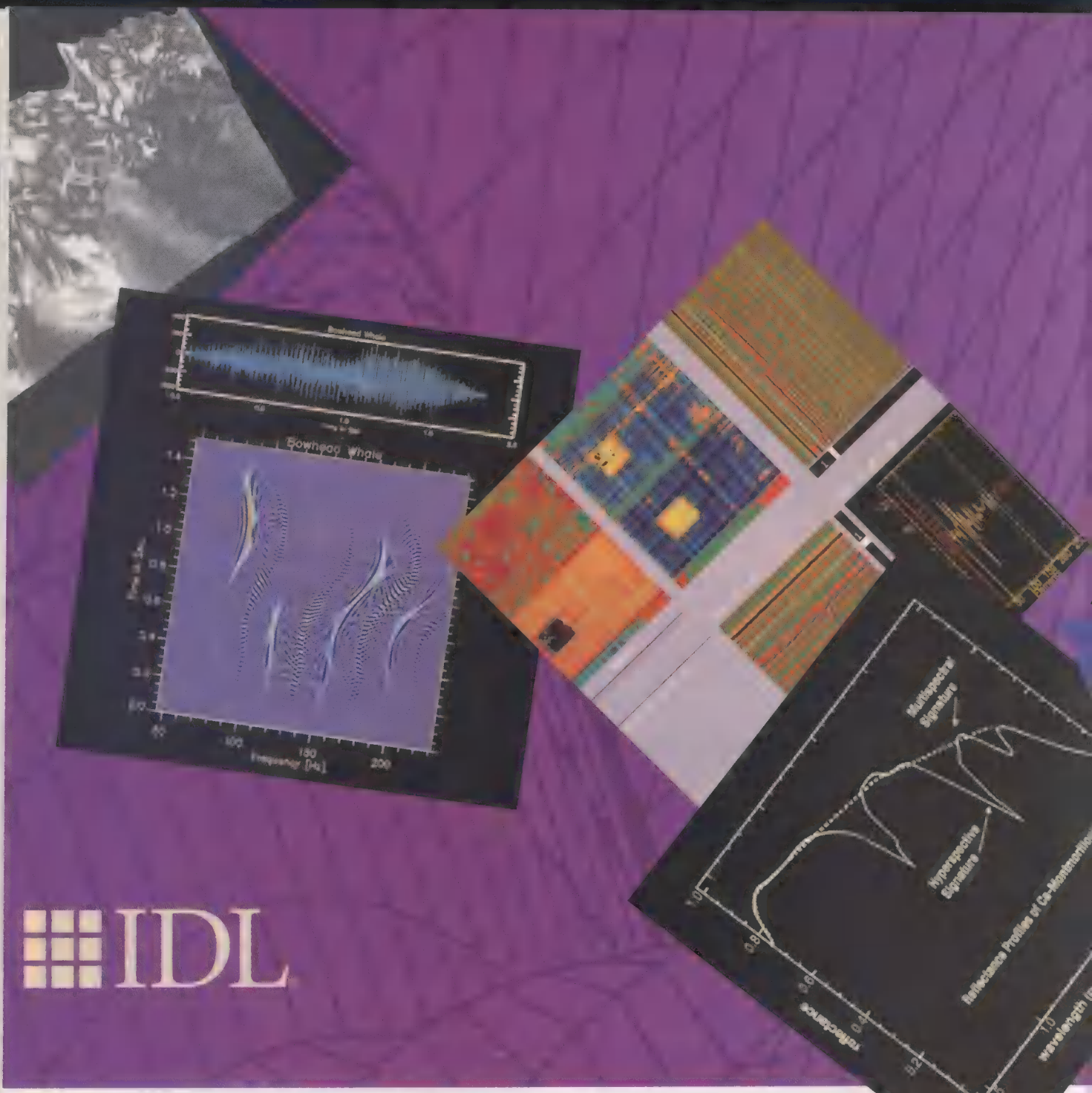
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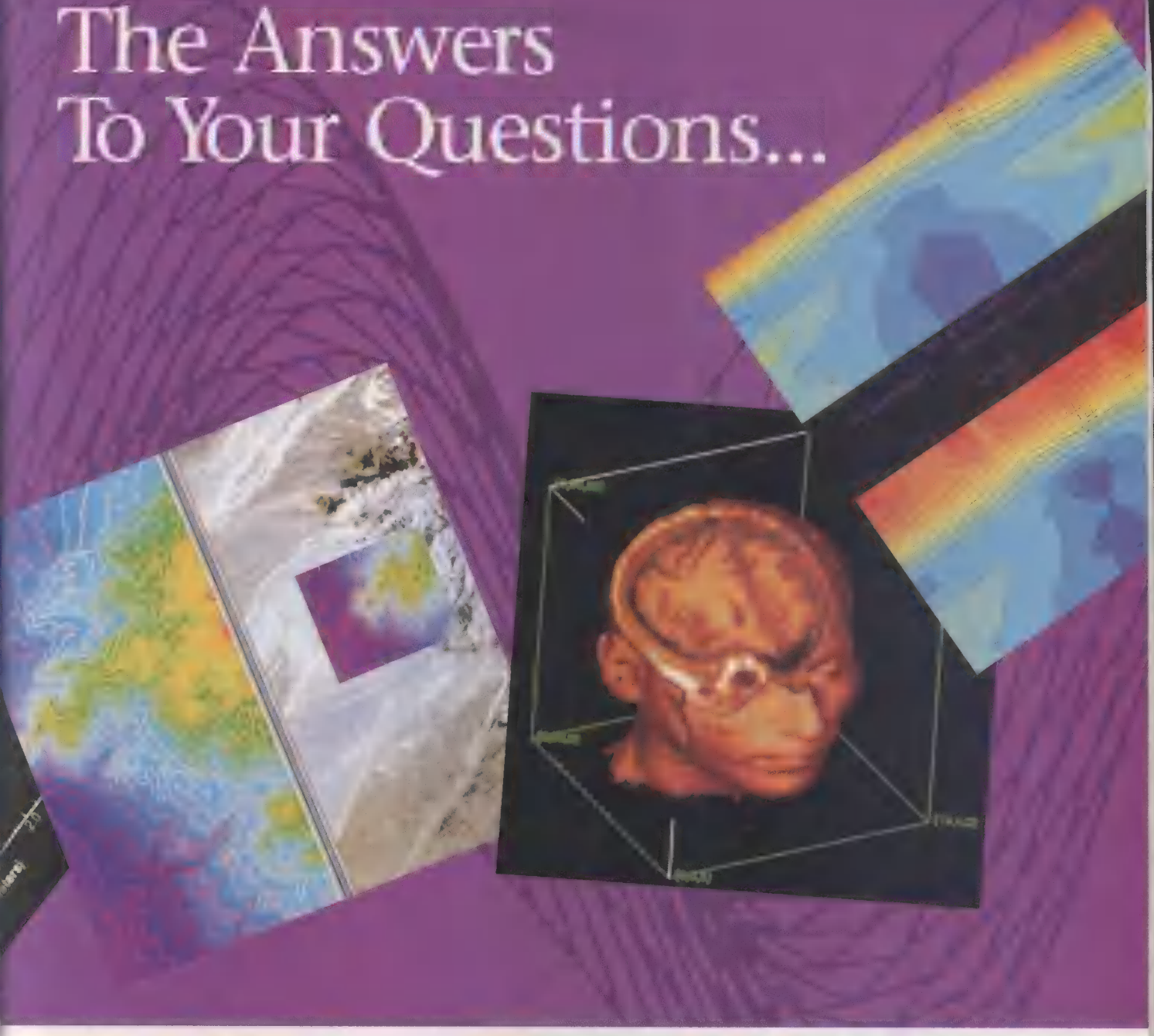
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Decision Support and Expert Systems: Management Support Systems, 4th edition. *Turban, Efraim*, Prentice Hall, Englewood Cliffs, N.J., 1995, 930 pp., $69.33.

The Papers of Thomas A. Edison, Vol. 3: Menlo Park: The Early Years, April 1876–December 1877. Ed. *Rosenberg, Robert A., et al.*, Johns Hopkins University Press, Baltimore, Md., 1994, 727 pp., $65.

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Network Security PRIVATE Communication in a PUBLIC World. *Kaufman, Charlie, et al.*, Prentice Hall, Englewood Cliffs, N.J., 1995, 504 pp., $46.

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LabTutor: A Friendly Guide to Computer Interfacing and LabVIEW Programming. *Eaton, John K.*, and *Eaton, Laura*, Oxford University Press, New York, 1995, 169 pp., $24.95.

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Routing in the Internet. *Huitema, Christian*, Prentice Hall, Englewood Cliffs, N.J., 1995, 319 pp., $42.

Intelligent Sensor Systems. *Brignell, John*, and *White, Neil*, Institute of Physics Publishing, Philadelphia, 1994, 256 pp., $95.59.

Linear Control Systems Analysis and Design: Conventional and Modern, 4th edition. *D'Azzo, John J.*, and *Houpis, Constantine H.*, McGraw-Hill, New York, 1995, 763 pp., $74.94.

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Living with the Chip: How the Chip affects your business, your family, your job, and your future. *Manners, David,* and *Makimoto, Tsugio*, Chapman & Hall, New York, 1995, 204 pp., $16.95.

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High-Frequency Analog Integrated Circuit Design. *Ed. Goyal, Ravender*, John Wiley & Sons, New York, 1995, 401 pp., $74.95.

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faults & failures

Showdown at Yucca Mountain

A Government plan to bury thousands of tons of fissile and radioactive materials under Nevada's Yucca Mountain is undergoing renewed scrutiny. A nuclear explosion cannot be ruled out, argues a new study by scientists Charles Bowman and Francesco Venneri of Los Alamos National Laboratory in New Mexico. The plan was earlier assailed because of fears that radioactive material would be released into the environment.

Devised by the U.S. Department of Energy (DOE), the plan involves as much as 70 000 Mg of plutonium, uranium, and other materials. One of its more likely variants involves containerizing the dangerous substances. Weapons-grade plutonium and/or spent reactor fuel containing uranium, plutonium, and other radioactive and fissile materials would be mixed with borosilicate glass, shaped into cylinders, and enclosed in steel containers. These would be placed in a labyrinth of tunnels and caves cut deep inside the mountain.

So long as the steel containers remained intact, there should be no risk of an explosion. The amount of fissile material in each canister would be below critical mass. The boron in the glass matrix would absorb neutrons that could otherwise contribute to a chain reaction.

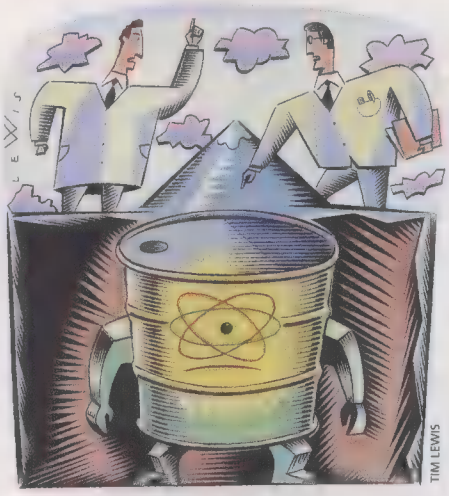
But Bowman, Venneri, and others have pointed out that the integrity of the steel containers cannot be guaranteed over the very long times involved. Quite possibly, especially if exposed to water, the steel would corrode away in far less than the half-lives of ^{239}Pu (over 24 000 years) and ^{235}U (7×10^8 years). So the system's ultimate safety should be determined by events after the containers disintegrate.

Once that happens, the report argues, the situation changes drastically. The fissile material is "free to disperse in the underground matrix where there are good moderators such as water or rock." (By slowing neutrons down, good moderators increase the likelihood of fission, whereas neutron absorbers, like boron, decrease the likelihood.)

The report continues: "Over time one must expect that the relative concentrations of water, rock, and fissile material could change and some of these changes could lead to criticality." (The criticality factor of a system is the ratio of the number of neutrons produced to the number lost through absorption or leakage. A ratio of 1 describes a system that is critical, like a nuclear reactor. Supercritical conditions, whose criticality exceeds1, occur with reactor accidents or nuclear bombs.)

It is widely believed that upon reaching criticality, systems will revert to subcritical conditions because of negative feedback. After all, criticality is most often increased by the presence of water. Supposedly, as criticality is approached, the system heats up, the water is vaporized and expelled, fewer neutrons are slowed, and the system reverts to a subcritical state.

But the Bowman-Venneri study finds that—depending on the mass and volume



of fissile material and the relative amounts of silicon dioxide and water that are present—the feedback could be either positive or negative. Positive feedback could bring about a self-enhancing condition, resulting in the "generation of explosive nuclear yields up to a few hundred tons." One example is a 2-meter sphere that contains 70 kg of ^{239}Pu in a 0.1 percent concentration along with water and silicon dioxide. "When this system becomes critical and the heat begins to drive the water out...it drives itself to higher criticality reaching its highest criticality in a dry supercritical state."

For their analysis, the scientists used a standard Monte Carlo method for calculating neutron and proton transport. They supposed ^{239}Pu was the fissile material and assumed a spherical geometry in their calculations.

The issue of the study's validity has divided the nuclear science community. An internal review of the Bowman and Venneri analysis by Gregory H. Canavan and his colleagues at Los Alamos maintains that the work has many flaws. Apparently, the calculations do not take proper account of the effects of elements present in the ground that are strong absorbers of neutrons. "When they are properly included," they reported, "it may not be possible to achieve criticality for the assumed conditions, even with pure ^{239}Pu." Nor has the compressibility of the rock been adequately considered, they believe. "Even if the mixture became critical, it would slowly heat and expand. Then its neutron flux would drop and it would cool," they state.

Another weakness was suggested by Rob P. Rechard, senior member of the technical staff in the Waste Isolation Pilot Plant Performance Assessment Department at Sandia National Laboratories, N.M. "I would argue that you can't get to the initial conditions that he starts from," Rechard told *IEEE Spectrum*.

"In a nuclear weapon you have to force the plutonium to extreme densities with high explosives, inject neutrons at precisely the same time, and hold it together long enough so that the material fissions at the same time," Rechard observed. "To claim that impure SiO_2 mixed with contaminated ^{239}Pu and initiated with stray neutrons can explode like a nuclear weapon is unreasonable."

On the other hand, support for the Bowman and Venneri calculations appears in a report by P.B. Parks and co-workers at the Westinghouse Savannah River Co., Aiken, S.C., facility. Partly on the basis of their own independent analysis, they believe that the possibility and consequences of a nuclear eruption in a nuclear waste site cannot be ignored. If an explosion occurred, the venting of fission products into the environment and damage to the repository would be major concerns. In short, the team advised that "unless the Bowman-Venneri thesis can be discredited on physical grounds, DOE must approach the question of geologic disposal of plutonium very cautiously."

More study is being urged. At Los Alamos, director Sig Hecker stated in the site newspaper of March 17 that the issues raised by the Bowman-Venneri report are important enough to receive the scrutiny of the scientific community. What is required, he said, is a more detailed analysis that removes the idealized assumptions and uses actual data to develop a probabilistic risk assessment of the hypotheses.

LINDA GEPPERT, *Editor*

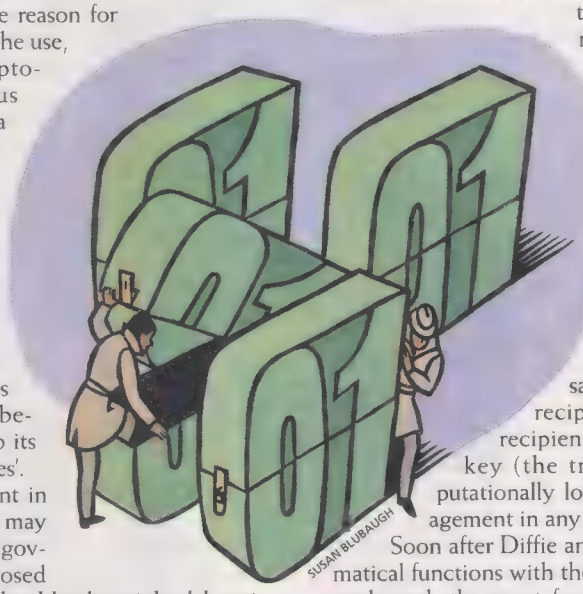
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The crypto quandary

Tooo encrypt, or not to encrypt—that is the question.
Whether 'tis nobler in the mind to suffer
The slings and arrows of lost privacy,
Or to take arms against the export controls,
And by opposing regain it?

Hamlet might not like my distortion of his immortal soliloquy, but he would probably sympathize with our agony over whether or not to apply modern cryptology to cyberspace. Every one of our transactions on the network reveals our status and habits in mounting detail to anyone out there who is listening, compiling, and selling. As our privacy slips steadily away from us, a remedy has arrived in the form of strong cryptography. One little problem, though—our friendly governments don't want us to use it.

Certainly, our governments have reason for concern. History is full of tales of the use, misuse, and exploitation of cryptography. I think of the ingenious wheels of the German Enigma machine and how, to hide the fact of its decipherability, Coventry was sacrificed to enemy bombing; the breaking of the Japanese code that, had it happened earlier, might have given forewarning of the attack on Pearl Harbor; and the scrambling of Churchill's conversations in the bunker beneath Whitehall. Wars have surely been won and lost because of a country's ability to keep its own secrets and uncover its enemies'.



Now we are at this strange point in time when our interests as citizens may not be aligned with those of our governments, who, after all, are supposed to act on our behalf. The question that Hamlet might debate is what our governments should do about cryptography. Some basic societal interests must be traded off, and on a national policy level, that debate either isn't happening or is being concealed from my skeptical ears. Also, it isn't very clear who has jurisdiction in this global domain. Exactly where is cyberspace anyway?

These days nearly every public meeting I attend to discuss the National (or Global) Information Infrastructure quickly degenerates into an impassioned and pointless discussion among us technologists about cryptographic policies. The informed policymakers among us keep quiet. I recall the Druids or the great stone figures on Easter Island. Perhaps there is wisdom in this enigmatic silence. Or maybe it is only a stoic facade.

It seems impossible that the governments with their giant mathematical fortresses of copiously funded secret research allowed the technology of cryptology to seep into the public domain. Yet it happened with the discovery in 1976 of public key cryptography by Martin Hellman and Whitfield Diffie.

I visited Hellman about that time in his office at Stanford University. He told me of his idea for one-way functions with trapdoors, and how such functions—if they existed—would make a new protocol for cryptography possible. I was filled with intellectual curiosity about the proposal, but I was very skeptical about its likely impact on the real world. "Marty," I said, "You do know about that government place where mathematicians work on this sort of thing? You know, the National Security Agency?"

Surely, I was thinking, those thousands of mathematicians in NSA knew about this stuff long ago. After all, this was just Marty in his little office at Stanford, and his training had been about the same as mine. I didn't know anything about codes and codebreaking, and therefore he couldn't either—Q.E.D.

As a kind of analogy with public key cryptography, let me tell what happened recently to a member of my family. To protect his anonymity, I use the encrypted name Doug. Anyway, Doug was on what proved an abortive ski vacation in Vermont. Leaving the watery slopes in 70° weather, he lost the clutch in his car and ended up having to abandon it for a week in Vermont, while he returned to New Jersey. Bad enough, but when he went to get his mail at his apartment, he remembered the only key to his mailbox was on the key ring in the car in Vermont. The postman, of course, went on dropping irretrievable mail in the slot. Hurriedly, Doug called the garage in Vermont and told them to mail him the key right away. And two days later Doug discovered what he had done—the only key to the mailbox was now locked inside the mailbox.

Doug's mailbox is like a public key cryptosystem. Anyone can put a message in the slot (by encrypting with the recipient's public key), but only the true recipient can retrieve it, by using his private key (the trapdoor in what is otherwise computationally locked). Still, the story shows key management in any cryptographic protocol is tricky!

Soon after Diffie and Hellman's work, a number of mathematical functions with the one-way property were proposed and evaluated, the most famous being the factorization of large numbers that led to RSA codes (Rivest, Shamir, and Adleman at MIT). The rest is, as they say, history. The opening up of cryptology to academics created an outpouring of results in the public domain, and today you can pick up any of a dozen textbooks and learn how to brew your own unbreakable codes (that is, codes that are computationally impractical to break during the time that you would care about). Of course, the government might prosecute you for carrying these books out of the country. Nonetheless, cryptographic knowledge is now widespread throughout the world. Oops! Export of the knowledge is illegal. The jury is instructed to disregard the earlier sentence.

The genie seems to be out of the bottle, and the governments are trying to stuff it back. In a sense their policy so far has been rather successful. Cryptography is hardly used at all, because export control has deterred the adoption of standards, which in today's computer world need to be global. If strong cryptography became standard and user friendly, then we would have our privacy reinstated. Citizens could transact electronic commerce with impunity. So could drug rings, spies, and unfriendly governments.

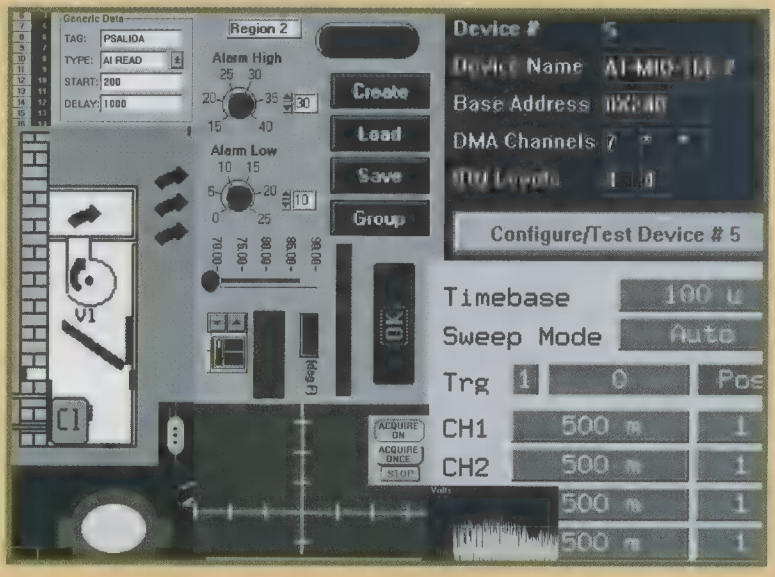
Aye, and there's the rub.

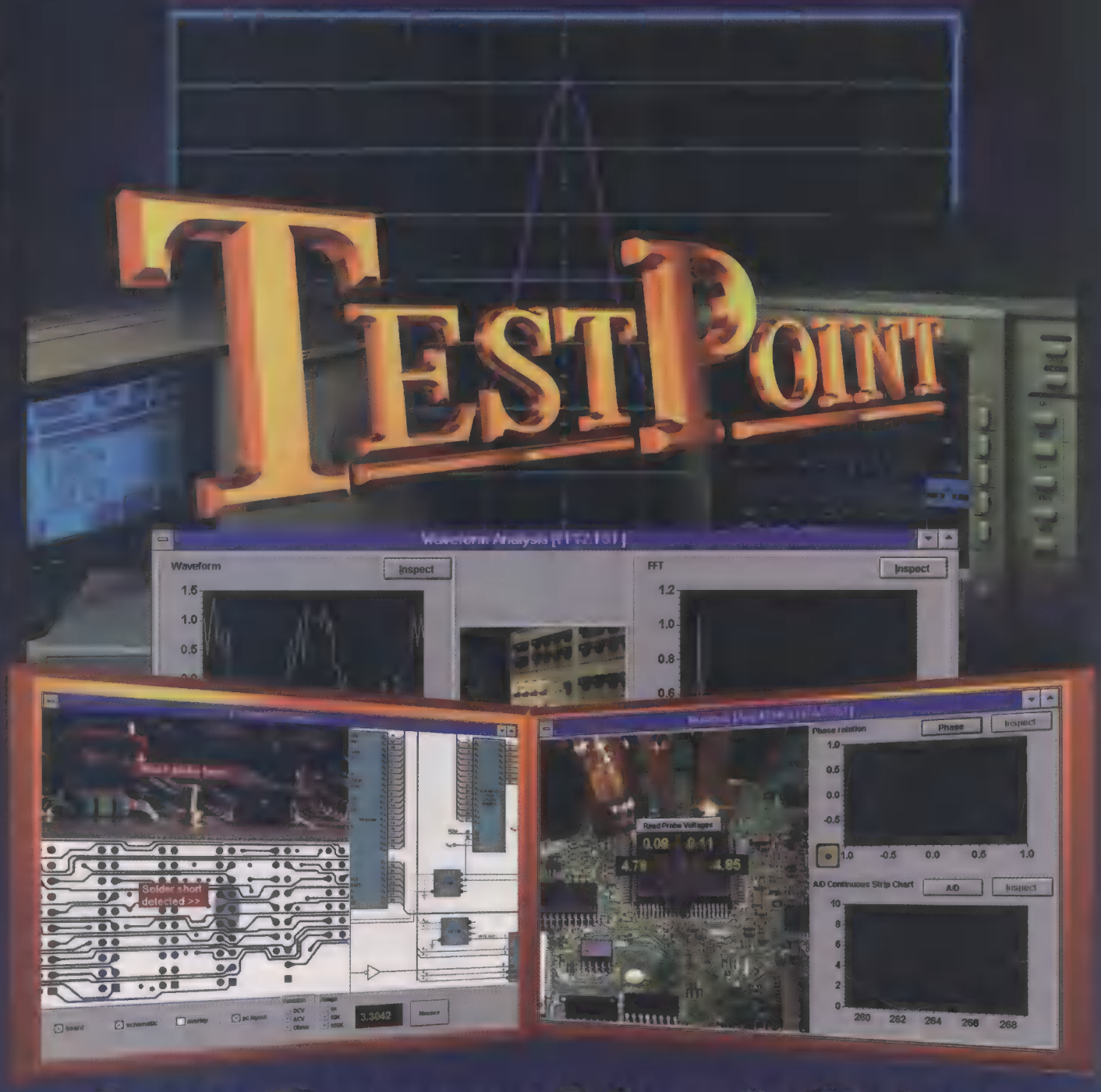
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WHETHER FOR TEST, MEASUREMENT, MONITORING, OR EVALUATION, data acquisition is part and parcel of system design in every field. Engineers and scientists are always on the lookout for software with which to meet the ever tougher demands of system evaluation without wrecking their budget. Fortuitously, as the PC and the workstation advance in performance, so, too, do software tools running on these platforms.

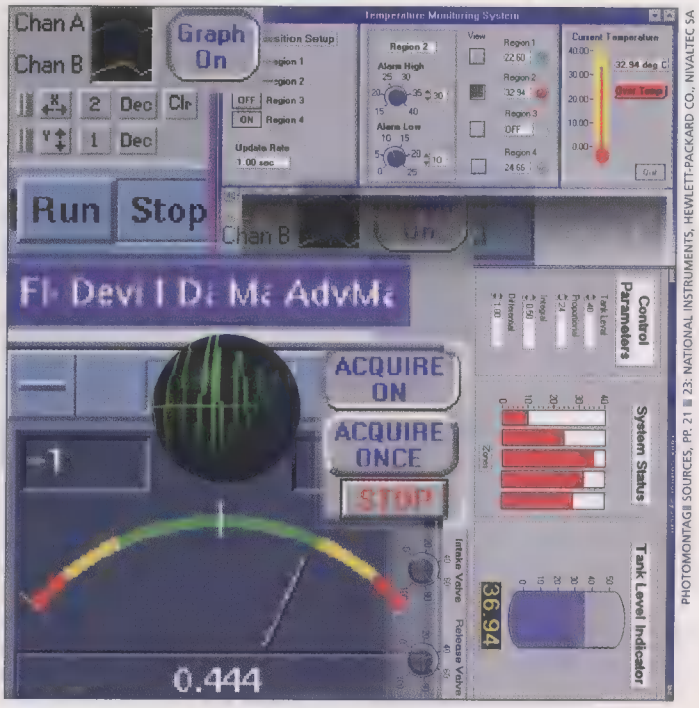
By now, the data acquisition category has fanned out into at least five subcategories, as reflected in the following article and table [pp. 32–39]. More than 50 packages are listed. Although not all-embracing, the list mirrors emerging trends and such new capabilities as double buffering, software analog triggering, and event-driven messaging. Vendors' telephone and fax numbers, as well as e-mail addresses when available, are included for the reader's convenience.

This is the first part of *IEEE Spectrum*'s annual focus report on software for engineering and science. Data analysis and visualization software are to be the main focus of the next part, which is scheduled for the fall.

As in earlier reports, this one, too, refers the reader to a variety of relevant sources for more details [see To Probe Further, p. 35].

GADI KAPLAN
Senior Technical Editor

Ranging from turnkey packages to virtual instruments, today's data acquisition tools help tackle the testing needs of increasingly sophisticated systems



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Multitasking and/or graphical programming and/or virtual instrumentation enhance 50-plus packages for use in process monitoring and control, test, measurement, and more

Choosing the right SOFTWARE FOR DATA ACQUISITION

RICHARD HOUSE
National Instruments

SOFTWARE FOR DATA ACQUISITION HAS evolved along much the same lines as spreadsheets and word processors. Fifteen years ago, it was the domain of a computer scientist elite, who typically worked with such languages as C and Fortran, or even low-level assembly languages, who wrote many software functions exclusively for specific applications, and whose platform of choice was the minicomputer. Integrated data acquisition computers then followed, but much programming time and effort still went into the development of, for example, text editors and data acquisition routines.

Today, the noncomputer scientist can use the PC for home finance and correspondence because the tools for each have grown handier and also generalized enough to serve in a variety of applications. Similarly, data acquisition (DAQ) software has evolved so that the nonexpert may employ the PC to automate DAQ systems.

In fact, such software has become not only more approachable but also more powerful. The latest packages can handle several DAQ functions simultaneously and at a high level of performance, even if long interrupt latencies are characteristic of the environment, as is true of Windows.

Despite all these changes for the better, it is still up to the user to pick the right package for the application. After all, while a spreadsheet could be used to write a letter, a word processor is more helpful because of built-in features such as word wrapping and spell checking. Conversely, for purposes of numerical computations, a spreadsheet is the only way to go, because a word processor is not designed to perform calculations.

Most PC users find it obvious when to prefer a spreadsheet to a word processor because they have a firm grasp of the strengths and weaknesses of different classes of general-purpose PC software. Likewise, engineers and scientists must fully understand the various classes of DAQ software if they are to be sure of selecting the right packages for their technical applications.

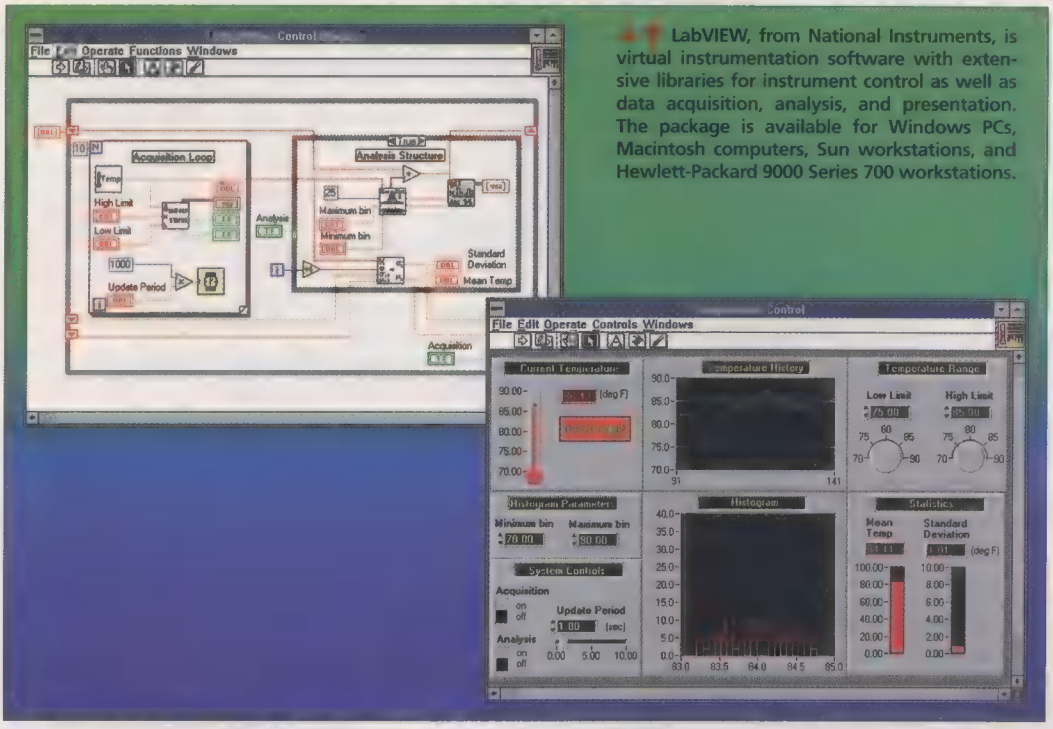
The subject of this report is any software that interfaces either with plug-in DAQ boards or with external DAQ boxes. Embedded in it is the binary code needed to configure the registers of the box or board for analog, digital, and timing input/output. The software controls the gain per channel, sampling rate, sampling order, digital levels, and counter and timer control. It also controls the transfer of data to and from the board or box by polling, interrupts, or direct memory access.

What DAQ software does

DAQ software serves applications like machine automation, process monitoring and control, instrumentation, and electronic test and measurement. In perhaps its most popular use, it measures temperatures from DAQ products interfaced to thermocouples, thermistors, resistance temperature detectors (RTDs), and IC sensors. Analog input is used for voltage measurement, signal and transient analysis, and data logging, and analog output for machine and process control, waveform generation, and variable voltage sources. In areas that are not electrically noisy, digital I/O lines are usually TTL-compatible. In relatively noisy environments—process control, for example—signal-conditioning hardware typically elevates the voltage levels of sensitive signals to make them less vulnerable to noise. Counter/timers serve functions such as pulse and clock generation, frequency shift keying, buffered counter operations, equivalent time sampling, relative time stamping of data, timed control of laboratory equipment, and frequency, event, and pulse width measurements.

Although many DAQ packages have analytic capabilities built in, it is not a prerequisite of this kind of software that it analyze the data it has acquired.

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LabVIEW, from National Instruments, is virtual instrumentation software with extensive libraries for instrument control as well as data acquisition, analysis, and presentation. The package is available for Windows PCs, Macintosh computers, Sun workstations, and Hewlett-Packard 9000 Series 700 workstations.

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Software that analyzes and displays data, without communicating directly with DAQ products, is classified differently, as analysis and visualization software.

Classes of DAQ software

The most popular general-purpose PC software can be divided into spreadsheets, word processors, database, and presentation software. Similarly, the most popular of the DAQ packages can be divided into turnkey, language interface, add-on tools, source code, and virtual instrumentation software [see table, pp. 32–39]. The software tools that fit in each class have similar types of developer and application for which they are best suited.

Turnkey software is the easiest kind to use, calling for no programming and needing very little setup. Packages of this sort are designed to control one specific application very well, but no other. If some extra capability is needed, then the developer must convince the software originator that such a capability should be added to the package.

A turnkey package usually has a graphical interface with menus for setting up the software. Often, the interface is designed to emulate a stand-alone instrument. With the turnkey approach, the user of a DAQ package needs no software (other than the computer operating system) to develop an application. A turnkey example is DSPworks from Momentum Data Systems, Costa Mesa, Calif.

Language interface software is a collection of DAQ subroutines or function calls from conventional programming languages, such as Pascal, Basic, and C. Whereas turnkey software is designed for nonprogrammers, language interface software is intended for developers who can program in conventional languages. Its users must write and compile code and link it to language interface software before any data can be acquired from a DAQ product. With the assistance of language interface software, developers can program the DAQ products not at the complex register level but with simple function calls. An example is `AI_VRead(deviceNumber, channel, gain, voltage)`, which reads the voltage applied to a specific input channel to and at a specified gain from the DAQ product device number. (This last identifies a particular product in a group—board, PC card, as specified by the PC Memory Card International Association [PCMCIA], or external DAQ hardware.) `DIG_In_Port(deviceNumber, port, pattern)`, another example of a function call, reads the digital pattern applied to a specified port of the DAQ product device number.

Once the data is acquired and stored in memory, developers must use their own skill as programmers or else turn to separate analysis and graphics lib-

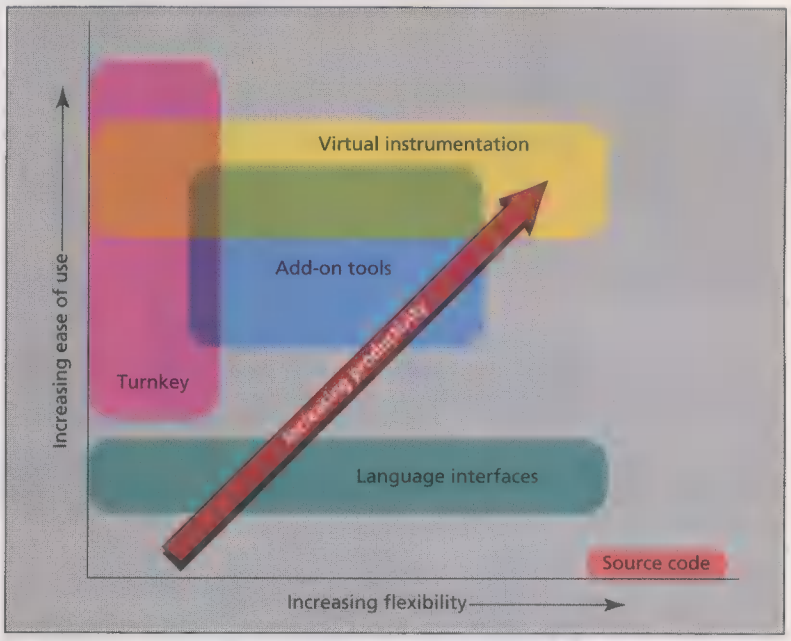


ILLUSTRATION: MORRIS KHAN

Turnkey data acquisition software is typically very easy to use but may lack the flexibility available to users of source-code–based software. Ranges of ease of use versus flexibility of different types of DAQ software available today are qualitatively depicted.

Defining terms

Direct memory access (DMA)*: a method by which data can be transferred to (from) computer memory from (to) a device or memory on the bus, bypassing the processor, which does something else.

Double buffering: the ability to acquire data into one memory buffer while processing data from another memory buffer.

Driver*: software that controls a specific hardware device.

Dynamic link library (DLL)*: a software module in Microsoft Windows containing executable code and data that can be called or used by Windows applications or other DLLs. Functions and data in a DLL are loaded and linked at run time when they are referenced by a Windows application or other DLLs.

Equivalent time sampling: the ability to sample a periodic signal at a rate faster than that of the analog-to-digital converter by using a counter- timer that offsets the timing of each sample in a controlled manner.

Event-driven messaging: the ability of a program to respond to events rather than follow traditional, sequential code.

First-in first-out (FIFO) memory buffer*: a buffer in which the first data stored is the first to be forwarded to the subsequent processing stage.

Interrupt*: a computer signal indicating that the CPU should suspend its current task to service a designated activity.

Interrupt latency*: the time required for the microprocessor to respond to an interrupt.

RTD*: resistance temperature detector; a probe that measures temperature based upon its coefficient of resistivity.

Software analog triggering*: a trigger that occurs when the software program identifies a user-selected point on an incoming analog signal. Triggering can be set to occur at ■ specific level on either an increasing or a decreasing signal (positive or negative slope).

Virtual Instrument*: in general, a combination of hardware and/or software elements, typically used with ■ PC, that has the functionality of a classic stand-alone instrument; specifically, a LabVIEW software module (VI), which consists of a front panel user interface and a block diagram program.

VxD: a virtual device driver, in this case a software module that adds new or enhanced capabilities to a Windows kernel. X is a variable identifying ■ specific device.

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raries to process and display the data. Developers must have the right compiler and be experienced in the language supported by the language interface software.

Some software of this kind includes examples to show how it should be used. While this is a great help, developers still must know how to program in the language before they can make the software work for their application. Examples of language interface software include Scientific Software Tools' Driver Linx and National Instruments' NI-DAQ.

Add-on tools software attaches DAQ capabilities to a development environment that the engineer or scientist already knows well, perhaps the Lotus 1-2-3 or Excel spreadsheet. The benefit is that developers use a familiar environment for their data acquisition application.

Visual Basic custom controls—software modules appended by vendors to Visual Basic to supply capabilities requested by customers—can also be considered add-ons for Visual Basic. They differ from language interfaces in that they are data acquisition files added to the Visual Basic application. Most DAQ software companies bundle the custom controls with their language interface software, blurring the distinction between add-on tools and language interface software for Visual Basic applications. An add-on example is Software Wedge from T.A.L. Enterprises, of Philadelphia [see lower photo, p. 28].

Source code software is ■ file, usually of C code, that developers can compile into the application for acquiring and controlling data. The source code is often treated as examples of what to do by developers who want to program the boards at the register level. The use of source code is by far the most complex way to program a DAQ system and the slowest for getting ■ system up and running, though it is often a help in reducing the code's overall size. In spite of this, source code software is losing ground because the latest DAQ boards are more powerful and much harder to program in source code. To use source code software, developers must be familiar not only with the programming language and the DAQ product, but also with the operations of interrupts, direct memory access, and I/O ports on the PC.

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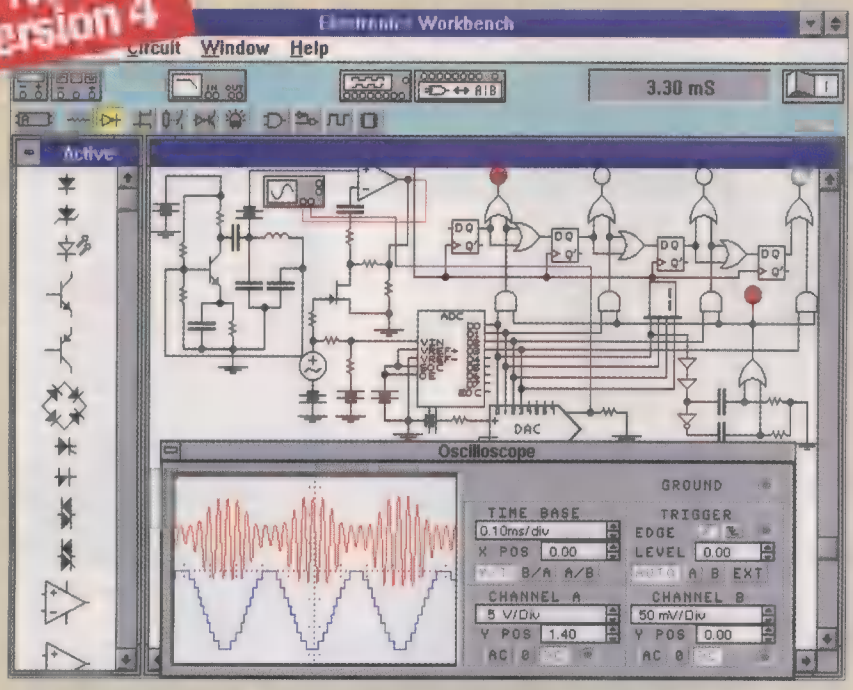
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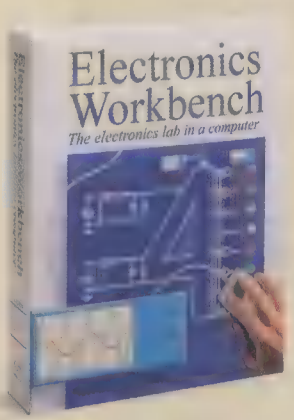
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with source code software, depending on the application and the operating system. With more advanced operating systems that address megabytes of memory and require very sophisticated programming to increase performance, these final benefits of source code software become less of a factor. DAQSourceCode from National Instruments is an example of source code software.

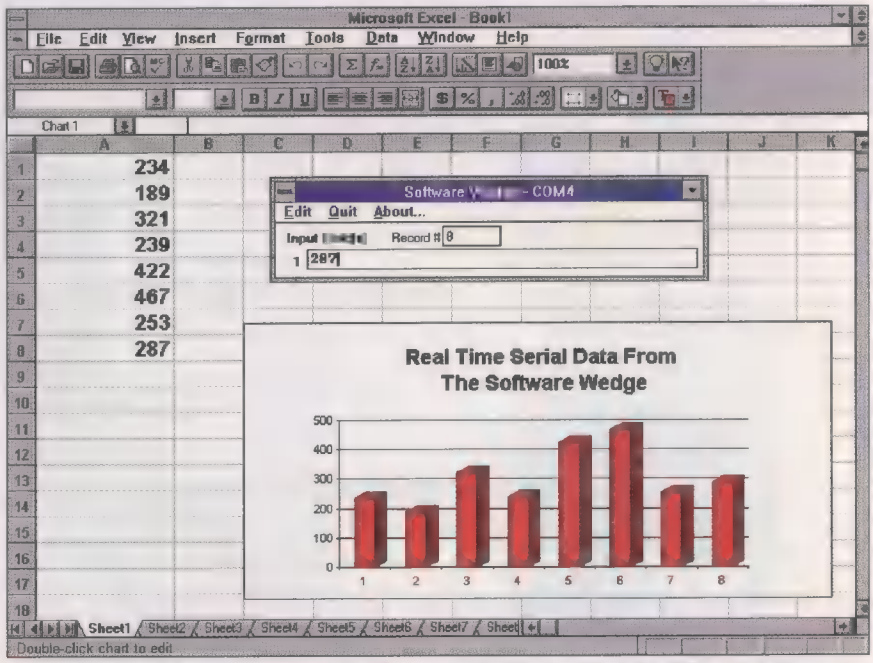
Virtual instrumentation software enables developers to design the custom instrument best suited to their application. Their virtual instruments may use off-the-shelf DAQ hardware products and the PC. Some companies also classify their interfaces to software of this kind as in itself being virtual instrumentation software. Most probably this meaning arises because the leading vendor in the field, LabVIEW, uses the term "virtual instrument" for those of its software modules that interface with other companies' DAQ products.

Instruments have almost always taken advantage of widely used electronics technology. For example, the first electronic in-



NATIONAL INSTRUMENTS

▲ **LabWindows/CVI, from National Instruments, is virtual instrumentation software for C programmers developing instrumentation laboratory and industrial applications based on Windows PCs and Sun SparcStations. It includes libraries for designing user interfaces, for acquiring, analyzing, and presenting data, and for networking. It also includes an ANSI C compiler, linker, debugger, variable-trace display, and memory-checking capabilities.**



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struments made use of the variable capacitor, the variable resistor, and the vacuum tube from radios, all available at low cost and with high quality. Similarly, oscilloscopes, analyzers, and computer screens have benefited from the large-scale manufacture and worldwide distribution of television sets, which use cathode-ray tubes. Today, virtual instruments exploit the increasing processing power and falling cost of desktop and notebook computers.

Traditional instruments are self-contained, with signal I/O capabilities and fixed user interface features like knobs, push buttons, gauges, and graphs. Inside the box, specialized circuitry, including analog-to-digital converters, signal conditioning, microprocessors, memory, and an internal bus, acquire real-world signals, analyze them, and present results to the user. The vendor defines all the instrument functionality—the user cannot change it.

In contrast, the virtual instrument utilizes the open architecture of industry-standard computers for processing, memory, and display capabilities, while off-the-shelf DAQ products interfaced to an open, standardized bus are the vehicle for instrument capabilities. The functionality of the virtual instrument is defined by the user. Virtual instrument examples include LabVIEW and LabWindows/CVI from National Instruments [see photos, p. 25 and p. 28].

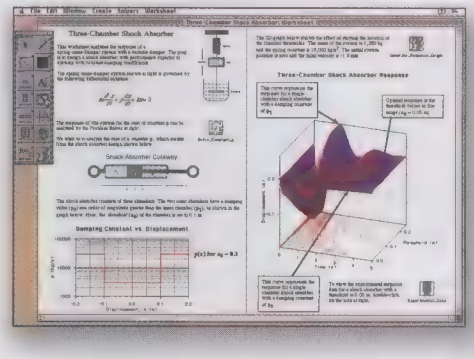
Scientists and engineers, in order to become more productive, have asked DAQ companies to produce both easy-to-use and very flexible software. The different classes of DAQ software have evolved accordingly, each having been developed for a different position on the ease-of-use versus flexibility curve. A wide range of both characteristics can occur within one class [see graph, p. 25]. For example, virtual instrumentation software is generally simpler to use but less adaptable than source code software, and vice versa. The packages available today, however, range from being very inflexible to being as flexible as some source code software.

The trend nowadays is toward virtual instrumentation software and away from source code software. Many more developers can use the first than can use the second—or can use language interface software. Conversely, virtual instrumentation software typically has more flexibility than turnkey software. Thanks to its ease of use and flexibility, it usually encourages the highest productivity. In addition, the fundamental concepts involved translate directly into bottom-line benefits for the user. The user, not the vendor, defines the ultimate functionality of the instrument. Affordable, flexible, and high-performance instrumentation is the fruit of enormous investments and technological advances in the computer industry.

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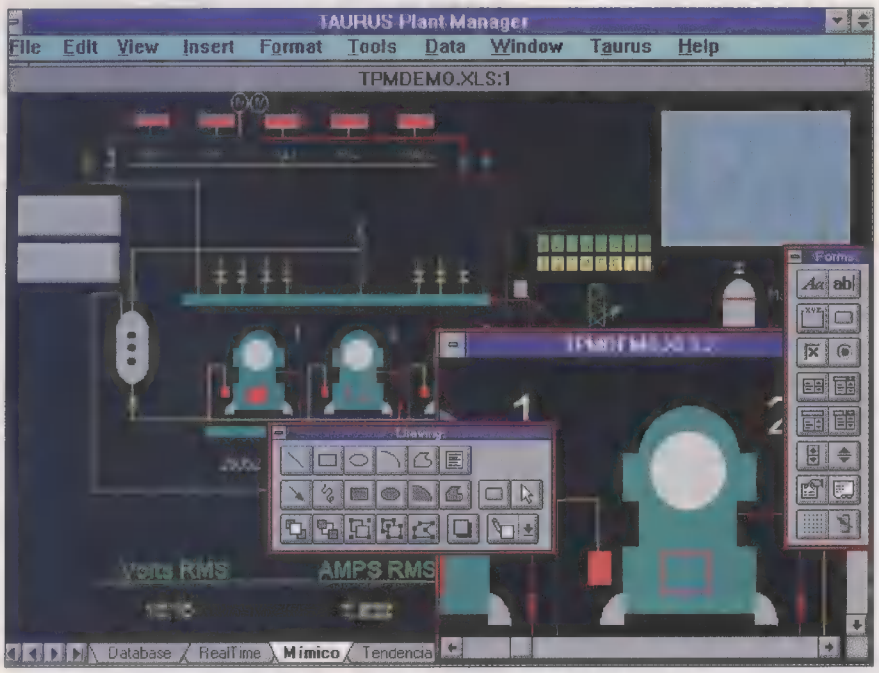
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An add-on to the Microsoft Corp.'s Excel 5.0 software, Taurus Plant Manager turns the static display of acquired data produced by a typical Excel spreadsheet into a dynamic one by updating such real-time data as voltage and current values [numeric cells, bottom left], and by dynamically displaying trends in plant parameters [upper right]. By clicking a mouse on such buttons as "data base," "real time" [upper left], or on an icon of, say, a motor, the operator makes the system execute a procedure in Visual Basic—a motor startup, for example.



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A visual driver panel, such as this one for a Hewlett-Packard oscilloscope, simplifies preparation for data acquisition by allowing the engineer or technician to set up the instrument without extensive programming [top]. Alternatively, a user who seeks more flexibility may access the instrument's input and output directly through a special I/O interface [bottom]. The driver panel is included in a library of more than 450 high-level visual driver panels supplied with Hewlett-Packard's HP VEE (visual engineering environment) software.

DAQ software varies in complexity from a few hundred lines of code, written by one developer in several hours, to hundreds of thousands of lines of code, written by teams of developers and measuring up to almost 100 man-years of development time.

In deciding which type of DAQ software to favor, the first consideration—or rather, considerations—should be the capabilities as defined by the application developer and the position that person or team wants to occupy on the ease-of-use versus flexibility curve.

Lack of familiarity with conventional programming languages at once rules out source code software and language interface software. Application simplicity, as in programs for temperature or signal monitoring, may point to turnkey software. If the application requires elaborate forms of control, future modifications, or a good deal of flexibility, then virtual instrumentation software could be the best choice.

DAQ products and OS diversity

The diversity of the DAQ hardware and operating systems that work with the DAQ software is yet another consideration. Some DAQ software will work with hardware on different bus architectures, including PC AT, parallel port, PC card, and the Macintosh. An application for use on a variety of hardware platforms need be developed only once by the users of such software. Some DAQ hardware products are more suited to performing low-speed, dc-class measurements because they have good stability. Other products are better suited to high-speed, ac-class measurements because they can transfer data to memory employing direct memory access, without using up the com-

putational bandwidth of the microprocessor. Check that the DAQ software chosen can handle the range of DAQ hardware required for the application.

Even if the application will always be on one platform, using only one class of hardware product, make sure the DAQ software runs on the operating systems that will be employed on that platform. For example, on the PC, an application could have anticipated only the DOS operating system a few years ago; but today the user may need a version that runs on Windows 3.1. For such an application, take care to confirm that today's DAQ software works under Windows 3.1, and that its vendor will have versions for Windows 95 in case the application needs to move to this new operating system.

The level of hardware capability that is supported by the software is a crucial consideration. The fact that the hardware has a certain capability is no guarantee that the software can work with it, especially if two manufacturers are involved.

Most DAQ software has functions for the basic DAQ functions, such as analog, digital, and timing I/O, because they are easy to write. These functions give application developers the ability to read and write single analog and digital values using the DAQ hardware products.

For most applications, though, this simple I/O capability is not enough. Moreover, the capabilities developers need are not always available in the DAQ software because the higher functionality capabilities would have required far more sophisticated programming by the company that wrote the DAQ software originally. Examples are double-buffering, analog triggering, event-driven messaging, or simultaneous use of analog, digital, and timing I/O functions.

Double-buffering allows the DAQ software to acquire data in the background while application software processes data in the foreground. The best way for the software to use double-buffering is for it to acquire the data into memory by direct memory access, so that the microprocessor has all its bandwidth to process the data in the foreground.

For such high-speed data acquisition applications as sonar or acoustic and vibration analysis, dedicated analog circuitry for hardware triggering is typically needed. For those relatively slow applications—measurements of temperature, pressure, or slowly varying direct voltage, for example—the processor typically can keep up with the rate of digitized data. Here software analog triggering comes in handy. DAQ products without hardware analog triggers can be set up for the software equivalent.

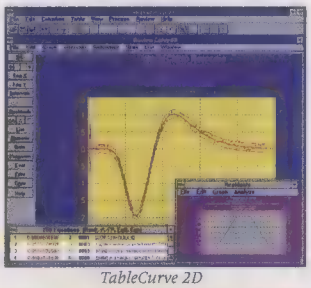
Using double-buffering, DAQ software can continuously acquire data in a circular buffer, overwriting old data points until software processing determines that an analog trigger condition has occurred. At this point, the data can be processed according to the application's requirements, which may be to save to disk, generate an alarm, or change the sampling rate.

Some DAQ software will lack analog triggering capabilities, or will lay claim to them, when all it has is a simple post-processing routine that acquires a block of data and then searches for the trigger point. Such software will be unable to emulate a hardware analog-triggered application, which could run indefinitely until a trigger condition occurred.

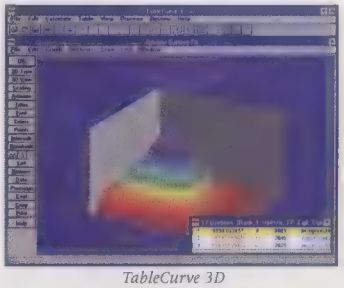
Event-driven messaging is a relative newcomer. Many years ago, programs were typically sequential, executing line one, then line two, and so on, although I/O routines were generally interrupt driven, allowing the computer to do other

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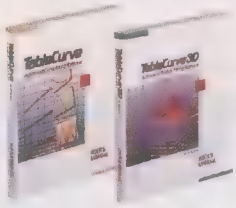
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tasks quasi-simultaneously. If the program had to wait for something to happen, it would loop, constantly polling to see if that one specific thing had happened.

Then with the introduction of graphical user-interfaces (GUIs), such as those with Windows, applications began to use a new format known as event-driven programming. In this context, an event is any operation that requires some response from the application program. Every time such an operation occurs, it produces a message.

Some DAQ software will send a message to the application whenever a user-specified event occurs. In this way, polling is eliminated and event-driven applications can be developed. Some examples of events include: a specified number of analog input samples have been acquired; the analog level and slope of a signal match specified levels; the signal is inside or outside a voltage band; a specified digital I/O pattern is matched; and a rising or falling edge occurred on a timing I/O line.

An example of event-driven messaging is an application feature that sends an alarm whenever a voltage exceeds high and low limits. Without messaging, the program would have to acquire the data, check if the data were above the high limit or below the low one, then acquire more data, repeat the check, and so on. With messaging, on the other hand, the developer first sets up the DAQ software to send an out-of-range message whenever the voltage on a channel exceeds the specified limits. Then, the program simply waits for an event to occur. If the application is running on a multitasking operating system, the microprocessor is at liberty to execute other programs.

More pitfalls to avoid

Simultaneous use of analog, digital, and timing I/O gives users the ability to perform multiple data acquisition functions at the same time. For example, an application that needs to acquire and generate a waveform at the same time requires a simultaneous use of analog input and output. The fact that the hardware and the software both have analog I/O capability is no guarantee that the combination can use analog input and output simultaneously.

If the application requires several DAQ products to be controlled by the computer at the same time, see to it that the software can control all of the products, simultaneously if necessary. In addition, make sure that the DAQ products have some capability to synchronize the timing and triggering if the application requires this.

Even though DAQ hardware may have a high sampling rate, the DAQ software may be unable to maintain that rate. Programmed I/O requires the microprocessor to control the conversion time and move every single data point. Having just this type of transfer capability is very limiting. If the microprocessor is determining the conversion time, the timing of the DAQ system will not be very accurate. With interrupt transfers, dedicated hardware timers can control the timing of the acquisition process, but the microprocessor is still left to transfer all the data. The most efficient data transfer is DMA, which uses a separate processor to move the data.

Microsoft Windows 3.1 has presented challenges to DAQ software developers because it has much longer interrupt latencies than does DOS. A number of DAQ hardware products compensate for the longer latencies by increasing the first-in, first-out (FIFO) buffer size on the boards.

A number of DAQ software developers have written virtual device drivers (termed VxDs, x being a variable denoting a specific device) to reduce the length of interrupt latencies of Windows to the levels of DOS. If the application will have to perform under Windows, the developer should be mindful of all the complexities that Windows adds to DAQ systems, and should make sure that the DAQ software not only runs in Windows, but has also been designed for Windows.

Typical engineering and manufacturing environments boast hardware from an assortment of vendors. In this case, software designed with an open architecture to support DAQ hardware from different

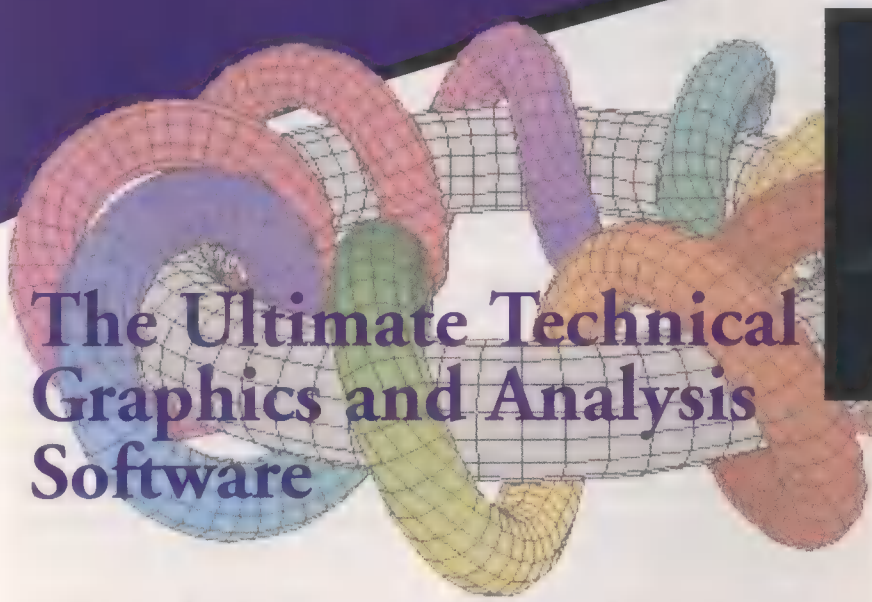
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Product name	Operating systems and prices	Class and description	Comments and features
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Genie 2.0	Windows 3.1: $495	(O) Has scripting language similar to Visual Basic (O) GUI simplifies set-up process	Supports DDE both as server and as client; also supports NetBios LAN connections
Audiolab Sistemas Eletronicos Ltda., Belo Horizonte - MG Brasil; (55+31) 271 1311; fax, (55+31) 222 0308; e-mail, angelo@fumsoft.softex.br			
OMNI 4.0	QNX 4.2 R 15 215	(O) Supervisory control and data acquisition package for power distribution management	Includes multiprotocol capabilities, visualization software, and interface with corporate database
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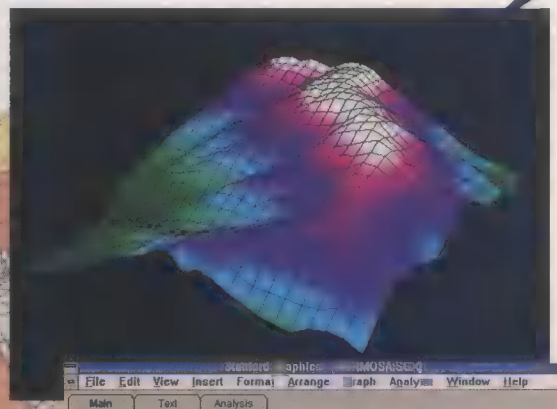
[See glossary on p. 39]

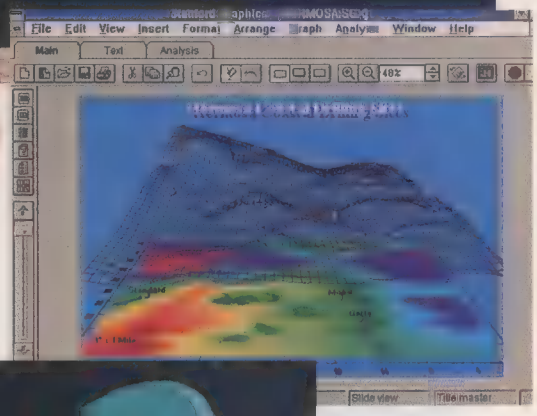
Continued on p. 34

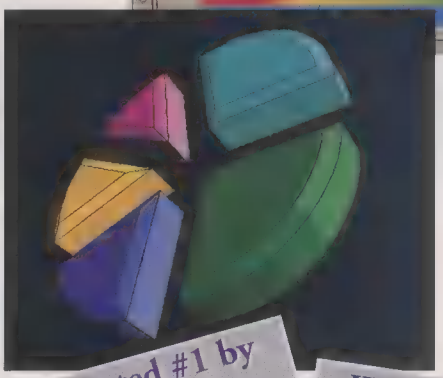
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vendors keeps a user from being locked into one vendor's set of hardware.

Be aware that using one vendor's hardware with another's software may create a problem, with the hardware vendor referring the user to the software vendor for help and vice versa. In addition, be sure to ascertain that all the hardware requirements are designed into the software.

Spend extra time up front to evaluate the tradeoffs of different classes of DAQ software and the software from different manufacturers. The payoff could be great time savings during application development. Ask the various vendors about the DAQ software considerations pertinent to the application. Find out if the manufacturer of the software has a demo disk and if so, get a copy and use it to get a better understanding of the product.

Finally, ascertain the flexibility of the software. It is important to make sure it is right for today's application, for tomorrow's changes to the application, and for future applications. ◆

To probe further

The IEEE Instrumentation and Measurement Technology Conference (IMTC/95) held last month in Waltham, Mass., included data acquisition topics (Conference Record No. 3910). The meeting next year (IMTC/96) will take place in Brussels, Belgium. Contact: Robert Myers, Conference Coordinator, 3685 Motor Ave., Suite 240, Los Angeles, CA 90034; 310-287-1463; fax, 310-287-1851.

The topic "C Under Windows 3.1 Simplifies Instrumentation Programming" is addressed by John Pasquarette in the January 1994 *Research and Development Magazine.*

The concept and development of the software-based virtual instrument (the laboratory virtual instrument engineering workbench, which came to be known as LabVIEW) is discussed in "An instrument that isn't really," *IEEE Spectrum*, August 1990, pp. 36–39.

Virtual instruments are dealt with by Ash Razdan in *Weighing and Measurement*, June 1993, pp. 6–17.

"Integration: The Future of Instrumentation" is discussed by Richard House in *Automotive Engineering*, March 1993, pp. 13–17. "Software Defines Data Acquisition" is addressed by Ray Almgren in *Canadian Electronics*, November 1993, p. 8.

About the author

Richard House is a data acquisition and instrumentation expert at National Instruments, Austin, Texas. He manages strategic marketing activities for the company's current and future data acquisition and signal-conditioning products for PC/XT/AT, PC Memory Card International Association, Micro Channel, Extended Industry Standard Architecture (EISA), and Macintosh computers and Sun SparcStations. He has published several articles and technical papers on PC-based data acquisition and instrumentation and often makes presentations on these topics at industry trade shows and conferences.

Acknowledgments

In preparing this focus report, *IEEE Spectrum* called on many sources but is specially indebted to the individuals listed below for their advice and guidance, though their association with the report should not be construed as their endorsement of any opinions expressed or products covered, nor of the accuracy of the statements made.

Advisors included Michael S.P. Lucas, professor in the department of electrical and computer engineering, Kansas State University, Manhattan; Raymond Turgel, physicist at the National Institute of Standards and Technology, Gaithersburg, Md.; Larry Stein, chair of IEEE P1284.3 Committee on software interface for high-speed bidirectional parallel ports, and president of FarPoint Communications, Lancaster, Calif.; and Adam Perine, instrumentation engineer, Boeing Co., Everett, Wash.

Data acquisition software

Product name	Operating systems and prices	Class and description	Comments and features
Data Translation Inc., Marlboro, MA; 508-481-3700; fax, 508-481-8620; e-mail, 741-0073@mcimail.com			
DSP-EZ	Windows 3.1: $995	(A) Optimizes DSP application development on Fulcrum data acquisition boards using Visual Basic GUI	DSP Basic language offers fast, easy access to data; high-speed plotting is included
DSP Lab	DOS 5.0, Windows 3.1: $2995 each	(L) Complete developer's kit for C programming of DSP for Fulcrum's C40-based data acquisition systems	Includes callable math, filters, logic routines, Spectron MicroSystems' SPOX O/S, and Texas Instruments' optimizing C compiler for Fulcrum's C40 processor
DT VEE for Windows	Windows 3.1: $995	(V) Complete visual programming packing for data acquisition, analysis (V) Powerful objects create functions such as FFTs	Cuts application development time; GUI shows data and analysis without programming by selecting input, data, and display objects from a menu and linking them
VB-EZ	Windows 3.1: $195	(A) Two VBXs perform data acquisition and analysis, and plot data in real time in Visual Basic	Includes many example programs to perform analog and digital I/O without programming
Dataq Instruments Inc., Akron, OH; 800-553-9006; fax, 216-666-5434			
WinDaq/200	Windows 3.1: $595	(T, L) Multitasking software for acquisition, display, and disk streaming of multichannel analog data	No programming required
Datel Inc., Mansfield, MA; 508-339-3000 ext. 285; fax, 508-339-6356			
PC-411 Board support	DOS: $95+ Windows 3.1: $50+	(V, L, S) Complete software support for Datel's PC-411 and PC-412 general-purpose analog I/O boards	Includes driven, virtual instruments, LabVIEW, DOS, and Windows support; also full source code
PC-414 Family support	DOS: $95 Windows 3.1: $50+	(V, L, S) Complete software support for Datel's PC-414 high-performance analog I/O board	Fully commented C and visual C source code available; has LabView library software; executable setup-configuration files
PC-430 Family	DOS: $495+ Windows 3.1: $50+	(L, V, S) Full DOS, Windows, LabView, and source code support for Datel's PC-430 high-performance analog I/O board with DSP	Includes driven libraries for high–performance data acquisition

[See glossary on p. 39]

Data acquisition software

Product name	Operating systems and prices	Class and description	Comments and features
Dianachart Inc., Rockaway, NJ; 201-625-2299; fax, 201-625-2449			
Instatrend 5.0	DOS, Windows: $875 each	(T) Data-acquisition and control software for process control and laboratory applications	Alarms, calculations, PID, PLC, voice phone interface; mouse-driven, pull-down menus
DSP Development Corp., Cambridge, MA; 617-577-1133; fax, 617-577-8211; dspdev@world.std.com			
DADiSP/LT	DOS 5.0: $495	(A) Provides control of data acquisition hardware directly from DADiSP software	Allows users to specify A/D collection parameters, collect data from the data acquisition board, and display data in a single step
Fluke Corp., Everett, WA; 800-44-Fluke; fax, 206-356-5116; e-mail, sunny@tc.fluke.com			
Hydra Logger for Windows	Windows 3.1: $595; with trending software, $995	(O) When teamed with a PC and any unit of Fluke's Hydra data acquisition series, this new package creates a 20- or 40-channel data acquisition system	Not limited to a specific application
GW Intruments, Somerville, MA; 617-625-4096; fax, 617-625-1322			
SuperScope II	Macintosh, Power PC: $1490 each	(V) Full-featured virtual instrumentation software	Flexible front panel design—high-speed continuous recording; on-line analysis
HEM Data Corp., Southfield, MI; 810-559-5607; fax, 810-559-8008			
Snap-Master Data Acquisition	Window 3.1 or higher: $995	(A, V) PC-based data acquisition software for real-time data acquisition, display, and storage—all with no programming required	Flowchart approach has instruments running in minutes; exceptional DDE communication; simultaneously acquires data from multiple I/O hardware
Hewlett-Packard Co., Loveland, CO; 800-452-4844 ext. 8498; fax, 303-754-4800 (HP VEE 3.0); ext. 599 (HP3412A BenchLink Meter)			
HP VEE 3.0	Windows: $995 Unix: $2995	(V) Graphical programming language for test and measurement applications	User creates desired look and controls an instrument (GPIB, RS-232, VXI, PC plug-in, GPIO, and LAN-based) in conjunction with text-based program
HP3412A BenchLink Meter	Windows 3.1: $150	(T) Turnkey software	Works with an HP 34401A digital multimeter or HP 53100-series counter to capture meter data, display it on the PC, and perform basic analysis and printing. Turns the PC-instrument combination into a basic data acquisition system. Captured data can be used in other Windows programs for further analysis or documentation.
Hyperception Inc., Dallas, TX; 214-343-8525; fax, 214-343-2457; e-mail, brian.carlson@hyperception.com			
AMPS	Windows 3.1: $1495	(V) Virtual instrumentation software that turns a PC into a set of instruments	Includes filter design, spectrum analyzer, two oscilloscopes, and digital recorder
Iconics Inc., Foxborough, MA; 508-543-8600; fax, 508-543-1503; info@iconics.com			
Genesis for Windows	Windows 3.1: $1595	(O) SCADA; MMI (A) Adding live and history data to Excel (V) PID loop control capability	Includes networking, DDE, OLE 2.0, ODBC for operator interface
Intec Controls Corp., Walpole, MA; 508-660-1221; fax, 508-660-2374; e-mail, intec@world.std.com			
Paragon TNT	DOS, OS/2, Windows NT: $2200+ each	(O) Graphical automation software can be tailored to any application requirement	Intuitive automation software for process monitoring, control, and information management; client/server modularity, font–windowing graphical interface
Intelligent Instrumentation Inc., Tucson, AZ; 602-573-0887; fax, 602-573-9671			
Visual Designer 2.3	Windows 3.1: $495	(O) Application generator for creating custom applications without programming	Block diagram building environment; supports DDE; supports wide range of data acquisition hardware, GPIB instruments, and serial devices
IOtech Inc., Cleveland, OH; 216-439-4091; fax, 216-439-4093			
VisuaLab	Windows 3.x: $395	(A) Visual Basic extensions for developing data acquisition applications	Turnkey data acquisition software for Windows applications expected soon
Keithley MetraByte, Taunton, MA; 800-348-0033; fax, 508-880-0179			
VTX	Windows: $399 (comprises three modules also available separately)	(A) Set of Visual Basic custom controls to speed development of Windows-based data acquisition	Modules available for data acquisition, analysis, and graphing; uses "wiring" concept—a visual linkage among different data acquisition functions—to help create custom solutions
Kinetic Systems Corp., Lockport, IL; 815-838-0005; fax, 815-838-4424; e-mail, dowling@kscorp.com			
Reality	DOS: $10 000 (includes VX Works target license, workstation, and one IOC)	(T) Software supports many channels and is based on open system concepts	Efficiently supports small to large systems and can be used with one or more Unix-based host workstations

Data acquisition software

Product name	Operating systems and prices	Class and description	Comments and features
Laboratory Technologies Corp., Wilmington, MA; 508-657-5400; fax, 508-658-9972; e-mail, info@labtech.com			
Labtech Control	DOS 2.0 or better, Windows 3.1: $1995 each	(V) Software that contains graphics to optimize the display of real-time data	Superset of company's Notebookpro plus 600 function blocks in Windows (400 in DOS); includes alarm processing and operator-initiated PID loop tuning; changes setpoints and alarm limits during a run
Labtech Controlpro	DOS 2.0 or better, Windows 3.1: $3495 each	As above	Includes all features of company's Control plus 2000 function blocks in Windows (470 in DOS); has hot-backup fault tolerance, integrated PID loop tuning, sensor voting for industrial control
Labtech Notebook	DOS 2.0 or better, Windows 3.1: $495 each	As above	Industry standard, easy to use; no programming required; supports over 500 data acquisition I/O hardware devices; handles 100 function blocks
Labtech Notebookpro	DOS 2.0 or better, Windows 3.1: $995 each	As above	Has all features of Labtech's Notebook, plus C-Icon Development Kit and Driver ToolKit; also supports RS-232 and GPIB instruments; handles 300 function blocks
Labtronics Inc., Guelph, Ont., Canada; 519-767-1061; fax, 519-836-4431			
Collect, Collect/W	DOS 3.1, Windows 3.1: US $295 each	(A, O) Software supporting simultaneous multiple-channel RS-232 data collection from virtually any serial device	Supports real-time data parsing and spreadsheet calculations; queries RS-232 instruments for data automatically at timed intervals; data can be sent to ASCII files or any of many foreground applications, including Lotus and Excel; 4-, 9-, and 12-channel versions available
LabWare Ltd., Wilmington, DE; 314-865-3789; fax, 314-865-0110			
LabStation Version 3.0	Windows 3.1: $3000	(O) RS-232 communication to analytic instruments and parsing of result files on network server	Stand-alone or as add-on module to Windows-based client/server LIMS, multiple instruments
Lucas Control Systems Products, Deeco Systems, Hayward, CA; 510-471-4700; fax, 510-489-3500			
Power–Assist Factory Automation Software	MS-DOS: (developer package) $1500 (run-time package) $1000	(O) PLC software	Includes alarm monitoring, triggered statistical process analysis, and real–time metering
Microcal Software Inc., Northampton, MA; 413-586-2013; fax, 413-585-0126; e-mail, tch_microcal@delphi.com			
Origin DAQ	Windows 3.1: $900	Data acquisition into a worksheet central data analysis and graphics package	Supports plug-in acquisition cards, RS-232, and IEEE-488 applications
Microstar Laboratories Inc., Bellevue, WA; 206-453-2345; fax, 206-453-3199; e-mail, sales@mstarlabs.com			
DAPview for DOS, DAPwindows	DOS: $95 OS/2: $395 (incl. OS/2 driver) Windows: $295	(O) PC software to control a data acquisition board with its own on-board processor running a real-time operating system; interfaces this real-time system with the host PC	Every DAP board has on-board intelligence: a coprocessor that runs application under its own operating system, free of any delays imposed by Windows—or other programs—running on the PC
Momentum Data Systems, Costa Mesa, CA; 714-557-6884; fax, 714-557-6969; e-mail, info@mds.com			
DSPworks	Unix: $2000 Window 3.XL: $495	(T) Data acquisition for DSP boards	Extensive board support—supports many DSP-type operations
National Instruments, Austin, TX; 512-794-0100; 800-433-3488; fax, 512-794-8411; e-mail, info@natinst.com			
LabVIEW	Windows, Windows NT: (base packages) $995 Windows, Windows NT, Mac, Power Mac: (full development systems) $1995 Sun: (full development system) $2995	(V) Graphical software for data acquisition, analysis, and presentation	Features a library of ready-to-use controls, graphs, and strip charts for quickly and easily building custom user interfaces and control panels; with LabVIEW, users build block diagrams as the executable programs; includes library for controlling plug-in data acquisition, DSP, and signal- conditioning hardware
LabWindows/CVI	Windows: (base package) $995 (full development system) $1995	(V) Visual development software for data acquisition, analysis, and presentation	A 32-bit, multiplatform development environment for building C-compatible test, measurement, and control applications; includes a built–in ANSI C compiler, linker, debugger, variable-trace display, and memory-checking abilities; has fully integrated libraries for data acquisition, analysis, presentation; users can incorporate external C source files, object modules, and DLLs into programs

[See glossary on p. 39]

Data acquisition software

Product name	Operating systems and prices	Class and description	Comments and features
NI-DAQ	Free with plug-in data acquisition hardware for DOS, Windows, Windows NT, Macintosh, and Solaris	(L) Driver software for data acquisition	An operating system for data acquisition that eliminates low-level programming and integrates hardware with the application programming environment; callable from programming languages such as Visual Basic, Borland C++ for Windows, and Microsoft Visual C++
SpectrumWare	Free with dynamic signal acquisition boards for Macintosh, Windows, and Sun	(T) Dynamic signal analyzer software	An easy-to-use GUI that simplifies the measurement of frequency response, power spectrum, amplitude spectrum, coherence, transient capture, cross spectrum, and total harmonic distortion
DAQSourceCode	Free with data acquisition boards for DOS and Windows	(S) Set of C source code routines for OEMs	Routines to implement the data acquisition and control functions for plug-in data acquisition boards
Nivaltec SA, Buenos Aires, Argentina; (54+1) 822 9120; fax, (54+1) 821 3804			
Taurus Plant Manager	Windows 3.1: $990	(A) Add-on for turning MS-Excel 5.0 into a data-acquisition tool with real-time visualization and analysis	Supports OLE2 and DDE; includes all the communication drivers for the major hardware brands
Omega Engineering Inc., Stamford, CT; 203-359-1660; fax, 203-359-7990			
Collect for Windows	Windows 3.1: $295	(L) Data collection from RS-232 instruments	Most RS-232 instruments supported
Omega Trend	DOS 3.1: $349	(T) Provides data recording and high-speed strip chart recorder emulation	Easy-to-use, high-speed, real-time display
Pioneer Hill Software, Poulsbo, WA; 360-697-3472; fax, 360-697-7730; e-mail, 73042.1756@compuserve.com			
Spectra Plus 3.0	Windows 3.1: $395	(T) Real-time data acquisition and spectral analysis using multimedia sound cards	Includes spectrogram and waterfall displays plus signal generator utility

[See glossary on p. 39]

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Data acquisition software

Product name	Operating systems and prices	Class and description	Comments and features
Prosig USA Inc., Dover, NJ; 201-366-3999; fax, 201-366-4949; e-mail, prosig@earth.planet.net			
DATS+ V.2.1	DOS 5.0: $1490 Unix/Motif: $3480 Window 3.1, NT: 2ndQ 1995	(L) Point–and–click user interface for driving data acquisition hardware	Supports third-party plug-in cards for PC; runs in transient capture mode and continuous mode to hard drive; Unix version features real-time frequency analysis
Sagian Inc., Indianapolis, IN; 317-328-3588; fax, 317-328-3589			
Camile TG	DOS, Windows: contact vendor	Data acquisition and process control software	Complete system including trending, logging, DDE, SFC, CFC, animated graphics, networking
Scientific Software Tools Inc., Paoli, PA; 610-889-1354; fax, 610-889-1556			
Driver Linx 2.0	Windows 3.X: $149	(L) Software DLL for developing data acquisition application in C/C+ and Pascal	Supports A/D conversion boards from eight vendors; supports WIN 32s, a programming interface by Microsoft for 32-bit code, and Watcom, a 32-bit C compiler
Driver Linx/VB 2.0	Windows 3.X: $149	(A) Visual Basic custom control for developing custom data acquisition application	Supports A/D conversion boards from eight vendors
Signal Technology Inc., Santa Barbara, CA; 805-899-8300; fax, 805-899-4344; e-mail, stisales@signal.com			
N!Power	Unix, VMS: $4795	(T, L) Object-oriented, X-Windows family of data acquisition and analysis software	Visual programming, menus, pop–ups, and symbolic command language
Strawberry Tree Inc., Sunnyvale, CA; 800-736-8810; fax, 408-736-1041			
Workbench	DOS 5.0, Macintosh 6.0.7, Windows 3.1: $995 each	(O) Icon-based, configurable software; no programming written in C; allows user-programmed icons to be added	Includes DDE, RS-232, IEEE 488, FFTs, statistics, trigonometry context-sensitive help, built-in tutorial, and X-Y chart

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Data acquisition software

Product name	Operating systems and prices	Class and description	Comments and features
T.A.L. Enterprises, Philadelphia, PA; 800-722-6004; 215-763-7904; fax, 215-763-9711			
Software Wedge	DOS: $159 Windows 3.X: $199	(A) Adds real-time data acquisition to any PC program	Collects data from any RS-232 instrument or serial device; has many advanced features and full DDE support
Software Wedge Pro	DOS: $295 Windows 3.X: $395	(A) Adds instrumentation control as well as real-time data acquisition to any PC program	Advanced data parsing, filtering, and formatting; expanded DDE support; faster data throughput
Ultraview Corp., Fremont, CA; 510-657-9501; fax, 510-657-0927; e-mail, ultrav@netcom.com			
Ultrasoft 2.4	Unix: $695	(L, S) Contains software for making data acquisition calls in C; also contains source code that can be compiled into any C program	Allows simultaneous multichannel A/D, D/A, TTL in and TTL out, with Windows graphical waveform display
Visual Solutions Inc., Westford, MA 01886; 508-392-0100; fax, 508-692-3102; e-mail, info@vsol.com			
VisSim	Windows 3.1, Win32s, NT: $795+ each	(O) Stand-alone application with data acquisition drivers	Visual block diagram programming; includes simulation and control capability, MMI for constructing control panels, data analysis capability, digital and analog I/O, counter timer, thermocouple linearization; supports common cards from Advantech, ComputerBoards, Keithley MetraByte, Data Translation

Abbreviations and glossary
(A) = add-on tools (for, say, adding data acquisition software capabilities to other tools, such as Lotus 1-2-3)
(L) = language interface software (for accessing data acquisition subroutines, say, from a programming language)
(O) = other (S) = source code (typically in C, for compilation into ■ data acquisition application)
(T) = turnkey software (tailored to a specific use)
(V) = virtual instrumentation ("custom instrument" design)
A/D = analog to digital; CFC = continuous function charts; D/A = digital to analog; DDE = dynamic data exchange; DIO = digital input/output; DLL = dynamic link library; DSP = digital signal processing; FFT = fast Fourier transform; GPIB = general-purpose interface bus; GPIO = general-purpose I/O (means input and output via a general-purpose interface board); GUI = graphical user-interface; IOC = I/O controller; LAN = local-area network; LIMS = laboratory information management system; MMI = man-machine interface; ODBC = open database connectivity; OLE = object linking and embedding; PID = proportional, integral, and differential (control); PLC = programmable logic controller; Scada = supervisory control and data acquisition; SFC = sequential function charts; VBX = Visual Basic extensions; VXI = VMEbus extensions for instrumentation; WIN 32s = a version of Windows that supports 32-bit applications (the programming interface for it is ■ subset of Windows NT).

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No rose garden for women in engineering

Precious few women, worldwide, are choosing careers in engineering. In the United States, women make up 51 percent of a professional workforce that includes scientists, engineers, mathematicians, doctors, nurses, lawyers, and teachers. Yet a paltry 8.5 percent of all engineers and 7.2 percent of electrical engineers are women.

The situation is grimmer in other industrialized countries. Women in Europe and Asia account for an even smaller percentage of the engineering workforce, ranging from 7.5 percent in France down to 2.9 percent in Japan.

Even more worrisome is the fact that most women who find their way into engineering do not thrive professionally. At technical conferences, few women give papers, fewer yet chair sessions or participate in panel discussions. An even smaller number make it into the top ranks of their organizations. At a time when affirmative action programs are under siege in the U.S. Congress, a Federal study has found that women and minorities are still grossly underrepresented in upper management.

To elucidate the factors that keep women from pursuing engineering careers, IEEE Spectrum *brought together a panel of eight successful women for a roundtable discussion, held at our offices in New York City on Feb. 22. The panelists work in academic, corporate, government, and consulting jobs within the Unites States. Perhaps the low percentages of women engineers in other industrialized nations may help to explain* Spectrum's *lack of success in finding panelists from European and Pacific Rim companies.*

The participants minced no words in laying out the problems that women engineers face and in sharing their strategies for dealing with them. They also offered suggestions to men and women engineers and their managers for making engineering a more rewarding profession for everyone.

From the tenor of the discussion, it was clear that all participants are fiercely independent, and unwilling to let anyone dictate what they might or might not do. This may be one factor that keeps the percentages of women engineers in the single digits. While a man considers engineering to be a career, a woman—to be successful—must also consider it to be a crusade. Besides brains and ability, a woman needs mettle to make it in engineering.

LINDA GEPPERT
Associate Editor



The participants were:

Eleanor Baum *(F), dean of engineering at Cooper Union in New York City. She is a director of Allegheny Power Systems Corp., Avnet Corp., and the United States Trust Co. She is also the president-elect of the American Society of Engineering Education.*

Diana J. Bendz *(SM), director of integrated safety technology for IBM Corporate Operations and Environmental Affairs, Somers, N.Y. She is a member of the IBM Academy of Technology and the chair of the IEEE Committee on the Environment, Health, and Safety.*

April S. Brown *(SM), associate professor of electrical engineering at Georgia Institute of Technology in Atlanta. She is a distinguished lecturer for the IEEE*

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Electron Devices Society, an associate editor of the Journal of Electronic Materials, *and chair of the IEEE Committee on Women in Engineering.*

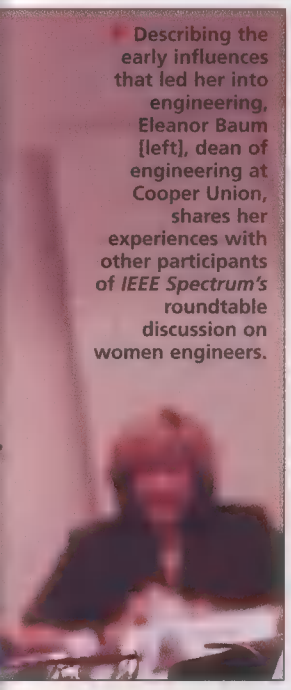
Jan Brown *(SM), an independent consultant in technology management, transfer, and commercialization, based in Austin, Texas. She has investigated sensor technology and applications at Schlumberger-Doll Research Corp. and at Fisher Controls. She is an associate editor of the* IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control.

Patricia L. Eng, *senior transportation project officer for the U.S. Nuclear Regulatory Commission in Washington, D.C. She is responsible for evaluating the inspection programs and policies affecting the storage of spent nuclear fuels. She also serves as vice president of special services for the Society of Women Engineers.*

Phyllis Hall *(A), the staff executive for publications at the IEEE with responsibility for magazines, transactions, journals, books, electronic products, and the IEEE History Center. She is the founder of the Athene book series, an award-winning series of feminist works now published by Macmillan.*

Julie Shimer *(M), vice president of the technical staff and director of advanced custom technologies at Motorola Inc. in Mesa, Ariz. Her prior work at AT&T's Silicon Technology Development Laboratory focused on silicon process development. She is an associate editor of the* IEEE Electron Device Letters.

Martha Sloan *(F), professor of electrical engineering at Michigan Technological University in Houghton, Mich. She was the president of the IEEE in 1993—its first woman president—and is on the IEEE Strategic Planning Committee.*



PHOTOS: JERRY VALENTE

Describing the early influences that led her into engineering, Eleanor Baum (left), dean of engineering at Cooper Union, shares her experiences with other participants of *IEEE Spectrum's* roundtable discussion on women engineers.

Getting started

SPECTRUM: Let's find out why each of you chose engineering as a career.

APRIL BROWN: My father is an electrical engineer and so is my sister. My first choice before college was psychology, but my father asked me to give engineering one year as an undergraduate and, if I was not happy, I could change majors. He thought that studying engineering was a good way for me to keep my options open. I kept going, first of all because a lot of people told me I could not do it and that's a great motivator for me. And I really do enjoy it—I like problem-solving.

JAN BROWN: In seventh grade I decided I was going to be an astrophysicist, and pursued that track until my freshman year in college when I took my first calculus course. I decided then I was not going to be a *theoretical* anything. (An *experimental* astrophysicist would work.)

So I continued in physics. Throughout my undergraduate training, every semester my advisor suggested that I major in something else. Maybe linguistics or sociology, but not physics. Partly because they said I couldn't do it, I said I was going to do it. But also I felt that—even if I did not continue doing it later—it was the only time in my life that I would do math and science. I could pick up a history book later, or maybe an economics text or sociology book, but would I pick up a math book? Probably not. Besides, I liked it.

The reason I got into engineering is that in the IEEE there's a Society called Ultrasonics, Ferroelectrics, and Frequency Control. Most of the people in the Society are physicists. There are a few electrical engineers, but the technology is ultrasonics.

SLOAN: My story has a little bit in common with both Browns. I was interested in physics in high school. I liked math and science. I wanted to go into physics and then my father suggested engineering. When I was accepted at Stanford, I was advised that if I had any idea that I might ever want to go into engineering, to start out in it because I could transfer out easily but couldn't transfer into it. That made sense.

I had gone the previous summer to a program at Northwestern's national high school institute for five weeks, which provided an exposure to all the fields of science and engineering. They taught us about very elementary ac circuits and I thought that was pretty neat stuff, so I signed up for electrical engineering, and I am still here these many years later.

SHIMER: I guess fathers are a big influence in a career choice. I was in second grade, I guess, about eight—this was just post-Sputnik—when my dad, who was an educator in our school system, brought home a series of comic strip stories put out by General Electric to encourage young men to go into electrical engineering. And I decided then that that was what I wanted to do.

In high school I got more interested in physics and did my undergraduate work in semiconductor physics. I got married when I was in college, so I went to Bethlehem, Pa., where my husband was living. I worked for Bethlehem Steel for three years as an electrical engineer. Then I said, "The heck with this, I'm going back to graduate school." I went into electrical engineering, which is what I was really interested in. I worked for 10 years at AT&T and the last couple of years at Motorola.

ENG: I have a lot in common with you, but it wasn't my father who got me into the sciences. I just started taking things apart at home and putting them back together. There were usually several pieces left over. My mother got angry with me when I couldn't get the alarm clock back together and told me I had to learn how to fix it right. In third grade I asked my science teacher why a ball bounced and she said, "When you get into high school, take physics and you'll learn." So I did and I fell in love with physics because it explained why everything works. In college, I majored in theoretical particle physics. But it was very frustrating to try to solve equations that were impossible to solve. So I went into nuclear engineering, where you could truncate after the third term in the series.

HALL: I now realize I'm a closet engineer. In the 1960s I became a computer programmer and systems analyst at a time when I was the sole support of a family of five. I had been working on the night shift of a newspaper and wanted to work days.

So I went to the personnel department and asked what I could do. And they said, "Well, we're looking for programmers." So I took a test and somehow passed and was whisked off to school at IBM. My job was to convert everything to data processing. And so, I guess I am, in

many respects, an engineer, although I wouldn't define myself that way.

BENDZ: I was always strong in math and science and my father had been a chemical engineer. He was very supportive, but my mother was always my biggest cheerleader. As an undergraduate, I was the only girl in my curriculum—it was chemical engineering, not electrical. But I've been in electronic development most of my career, and I've been very active in the IEEE because that's really my field of activity.

BAUM: I was one of these good kids who did well in most things in high school. I liked math and physics, but honestly found it more difficult than all the other subjects. When the time came to talk about college, the boys in my class who were taking advanced math and science courses said they wanted to be engineers. I really didn't know what it was about. I was supposed to be an elementary school teacher or nurse—because that's what women did. I got angry and said I was going to be an engineer, too. Of course, everyone told me I was crazy, including my parents.

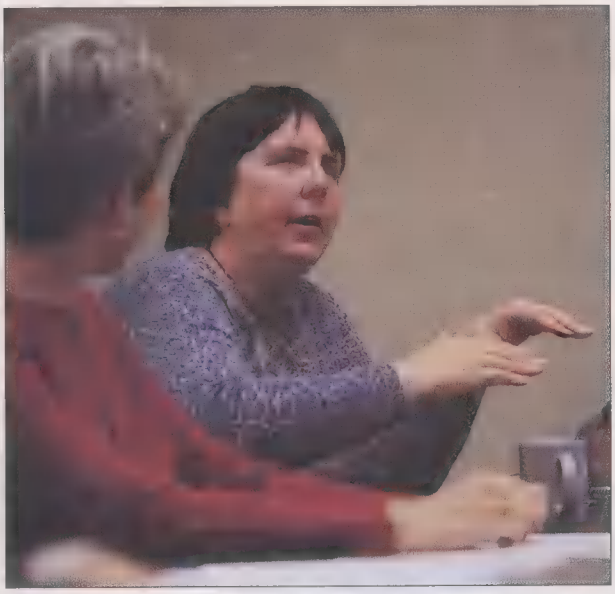
But I got into an engineering school and studied electrical engineering for a wonderful reason. I was terrified of machinery. I had never taken anything apart. I hated high school chemistry and the only other kind of engineering I knew about was electrical engineering. Heck, I could plug things into the wall, so what was the big deal? No problem! And I found that I liked most of it in college. But I felt very conspicuous—I was made to feel very uncomfortable in a lot of classes and I'm not a shy flower.

I went to City College in New York, which was not a nurturing environment. I stuck with it and it was interesting enough that I worked in industry a number of years. Then I went back to get a Ph.D. so that I would never have to work again in the kind of horrible job I had in industry with my bachelor's degree.

My mother denies it now, but she really went off the wall when I decided to study engineering. For her, the important thing was that people were going to think I was peculiar and I would never get married. And in my mother's frame of reference at that time, that was the most important thing in the world.

JAN BROWN: My parents always thought it was a phase that I was going through. I remember when I finally got my Ph.D., my mother said, "Well, this isn't a phase, is it?" She was very disappointed for the very same reason. I was supposed to be married.

BAUM: My mother was even more upset when I wanted to go to graduate school, because according to her—and she had thought this through—I was limiting the available group of men. I was becoming too educated. No one was going to want me. I remember that expression—and her incredible relief when I got married.



'A positive influence for the generation now in pre-school is the wonderful things being done with computers.'

MARTHA SLOAN, *engineering professor*

I wound up in engineering education at a time when I had a couple of kids and it seemed like a good option. That was a time when having children and working was just as shocking as being an engineer. My husband's family was absolutely mortified. It meant people would think that he couldn't support me. Why else would I work? I should sit home, bake cookies, and have a happy life watching the success of my children and my husband and not think in terms of a career.

Discouraging forces

BAUM: You know, there are a couple of recurring themes. One is that, obviously, all of us who went into engineering or physics were good in math and science in high school. The second is that it seems to me that none of us were encouraged by high school teachers and guidance counselors. Those of us who had an engineer in our families were encouraged by our families, otherwise, not.

APRIL BROWN: I was discouraged by teachers.

BAUM: Me, too. In college as well.

JAN BROWN: I would say the faculty discouraged me as an undergraduate, but in high school all my math and science teachers—male and female—were great. Teachers respond well to good students, male or female.

BAUM: My teachers responded well, but they didn't encourage me to go into engineering. Since I was very good in math, they encouraged me to think in terms of becoming a math teacher.

SHIMER: I had a female guidance counselor who had a master's degree in geology and had chosen to go into education because of the pressure she felt, and I believe she was trying to push that off on me. She said, "Why do you want a career in science and engineering?" She was actively and sincerely trying to talk me out of applying to institutes of technology. She was saying that I should give myself an option to get out of a technical career.

BAUM: Another very discouraging thing was that when I passed the doctoral qualifying exam, people had the attitude that I was taking a place that a man really needed. I didn't need it because I would have a husband to support me.

SLOAN: In fact they had the draft in my college days. By being in the top half of my class I was knocking some guy into the bottom half and possibly into the army. Stanford's response was to separately rank the women and the men. I was the only woman. But I had to be separately ranked to save one person from being drafted.

ENG: I'm mentoring about 20 young women between the ages of 14 and 21 and the single biggest problem they have is not in high school. There we have so many intervention programs through various societies to encourage young women to pursue math and science.

It's not until they get into college and encounter some professors from overseas that the problem starts. What I'm hearing is that the professors who are raised and educated here are much more responsive and more nurturing of the women students than the professors from cultures where women have historically stayed home and raised the children. Based on information from the student sections of the Society of Women Engineers, we lose a lot of bright young women because these professors are

downright denigrating. They tell you, "You know, you can take this class, but you're never going to get a job because you don't have the skills that it takes." And it's getting much more blatant.

BAUM: At many colleges now, there is a critical mass of women studying engineering. So they no longer need to feel like pioneers. Women who are now in engineering programs don't feel weird. The kinds of things that they do face, in addition to the problem of foreign faculty, is an assumption on the part of a lot of older professors that all students come from the same kind of gestalt that they themselves came from—knowing how to fix cars and having the skills that go along with that. I think there has to be an understanding that neither women nor most minority students have had those kinds of experiences and that you can't explain things in those terms. Schools have to make a major effort for diversity of faculty. There aren't enough female role models on engineering faculties.

APRIL BROWN: The percentages may be there overall. But when I talk to women undergrads, there is still a feeling of isolation because they are separated. There needs to be some intervention on the part of faculty members in certain experiences—for example, engineering laboratories. There's some indication—and this was also my personal experience—that particularly in the lab, women students are isolated.

BAUM: As data takers, right?

APRIL BROWN: Yes. Data takers. They have experiences that don't help their self-esteem in general and some intervention by the faculty running the labs needs to occur. I have a good friend at Georgia Tech, a male faculty member who is very proactive about this. He looks at how men and women are participating, and tries to see that everyone gets equal hands-on experience. If the women students tend to feel intimidated because they don't have the mechanical experience, he makes sure they have the opportunity to get their hands on the equipment.

SLOAN: On the other hand, a positive influence for the generation now in pre-school is the wonderful things being done with computers. You can observe pre-schoolers using the computer without fear. The feeling that they can be in command of a computer and a mechanical system will be a help to the girls that are coming up.

BAUM: On my campus and on many others, the faculty assumes that if a women goes into engineering, she is a super student. And it puts such unfair pressure on women. It's okay for men to be C students—it should also be okay for women. But somehow we don't allow that. They have got to be super-achievers. And indeed, studies of women who go into engineering find that they tended to be super-students in high school.



'Studies of women students who go into engineering find that they tended to be super-students in high school.'

ELEANOR BAUM, *dean of engineering*

SHIMER: The signal we're sending is that it's very tough for a woman to get into engineering. She has to be very good, but any old guy can be an engineer. The perception starts before they get to college, and if the professors don't pay as much attention to the average female student as they do to the average male student, then it just gets reinforced.

BAUM: Or they think there's something terribly wrong if the females in the class don't have much higher grades.

JAN BROWN: I heard an encouraging thing the other day from a faculty person who said that as they've increased the number of women in their incoming classes, they are getting more women who are average students. They're not just at the top of their class.

BAUM: That's good news. I think that's unusual nationally, though. The norm is still that the women tend to come in with higher standardized test scores and higher high school grades, or else they're discouraged from going into engineering.

APRIL BROWN: While we can do all these things to help engineering schools educate, surveys of Georgia Tech students indicate that the faculty are great, the programs are great. The biggest problem is that the women are not fully accepted by their male peers.

BAUM: In cities like New York where you have a diverse population with many immigrants, it becomes a big problem with our students. We're seeing a lot of that right now with Asian women.

Several times I've walked into a ladies' room and found weeping young Korean or Vietnamese women whose male student so-called friends have made them feel terrible. "How dare you ask a question? It's unfeminine. It's arrogant. You're supposed to sit with your eyes down and your mouth shut." These women are really torn. They have not been born in this country, and come from a home environment where if a man says this to them, it makes a lot of sense. It's a big mess.

SHIMER: It's not fair just to put the blame on other ethnic groups. It's very pervasive. It still surprises me that the male attitude hasn't changed that much from when I was in school. It's this attitude that "I wouldn't want a wife who makes more than I do; I wouldn't want a wife who has a higher education than I have."

People have said things to me like "You have a job that a man should have"—not in the past few years so much, but in the '80s when there were layoffs. I was occupying some deserving male's spot—not on the basis of performance, but because he had a family to support. My husband worked, so I had no right working. I think those attitudes continue to exist, and changing economic factors cause them to ebb and flow.

JAN BROWN: Even if we go back to high school; what guy wants to date a girl that has higher grades than he does? That was a big thing in my high school.

The engineer's image

BAUM: A basic problem is that engineers have an absolutely lousy image. They don't have a professional image. We've so splintered ourselves into separate disciplines that nobody speaks for the profession of engineering.

SHIMER: Elementary and junior high school teachers don't know what engineers do, who engineers are, or what engineers look like.

JAN BROWN: And whose responsibility is that? It's our responsibility to do something about that image.

APRIL BROWN: Well, it's the media's also.

BAUM: Thank God for "Star Trek"!

JAN BROWN: You know what's really bad? Walt Disney, *Beauty and the Beast*. The inventor father and the smart daughter, totally ostracized by the town. Nobody liked the engineer. Nobody liked the girl because she liked to read. They gave her total grief. Other Walt Disney films have the same themes. Anyone who is a scientist is either mad or a total nerd. This is what our two- and three- and four-year-olds are seeing.

HALL: There's also a naming game going on here. When engineers do wonderful things, they don't call themselves engineers anymore. Do you think of Bill Gates as an engineer? Bill Gates is an entrepreneur. We could name many prominent engineers, whose contribution anyone would recognize, but I don't hear the word "engineer" tacked onto what they are. I think of the wonderful stories of Edison or Bell, but I never thought they were engineers. They were inventors.

Maybe women in engineering find it so tough because male engineers have very low self-esteem, so somebody has to be even lower. That's different in other disciplines. I'm learning from the IEEE what a low self-esteem our practicing engineer has.

BAUM: Is it because they are the first generation to be educated as compared with most other fields? If you have parents who are college educated, majoring in literature or thinking of law school makes sense. But if you have a blue collar background, engineering is almost the first boot-strap kind of profession.

JAN BROWN: More than that, it's the image of the engineer in society. You don't tell people you're an engineer, even when you're successful.

BAUM: Of those women who either are practicing engineers or are studying engineering in college, 75 percent have a father or brother who's an engineer. It's almost like you have to know and respect an engineer to get through that negative image.

HALL: Maybe engineering is hereditary.

ENG: No. No.

APRIL BROWN: [Representative] Pat Schroeder [D–Colo.] was speaking at a conference on encouraging more women to go into math and science, and she said that having a TV show like "L.A. Engineer" could have a tremendous impact.

HALL: It won't be called "L.A. Engineer." It will be called "L.A. Entrepreneur" or "L.A. Inventor."

JAN BROWN: Why can't we have, in *Red Book* and *McCall's* and *Popular Mechanics* and other magazines read by everybody, profiles of women engineers?

I was talking to [Tsuneo] Nakahara [vice chairman of Sumitomo Electric Industries Ltd., Osaka, Japan]. He has a daughter who is a computer engineer. I asked him about the changing role of women in Japan and the single best thing we can do to change the image in Japan. He said that popular magazines should profile women engineers.



'I see women who are well qualified and educated but who are not opting for a career.'

DIANA BENDZ, *IBM executive*

BAUM: For the last 15 years I have been trying to get a magazine like *Seventeen* to cover anything on women in engineering, and I have gotten absolutely zero interest.

APRIL BROWN: If computer engineering is the No. 1 job for the future, then there needs to be some press related to how attractive a career it could be for women.

BAUM: And going back to campus: the Society of Women Engineers will very often run a program with industry women as speakers and role models, and the audience will be all women. I think it's terribly important for men to see successful female role models. You've got to sensitize university communities to do that. I think that's true with minorities, too. You have a successful black engineer and no one meets him but your black students. You want your white kids to meet him.

Gender issues

HALL: Women in engineering have successfully made themselves genderless. They feel that they must be seen as professional engineers. Women in other disciplines say, "I am a woman and I am a scientist and I bring something special to my science." Women engineers are divorced from that. They don't even recognize that they can say they have a gender, both to themselves and to others.

JAN BROWN: It takes 2 hours in any conversation with a group of engineering women before they can recognize that something is different about them from a male engineer; and that that's okay.

HALL: Maybe even positive.

SHIMER: Up until now, engineering has been such a male-dominated profession that all the approval comes from men. Women are not used to looking to other women for approval or for support. If I tell you that you did a good job, you say, "Well, you're another woman" and discount it. I have paid a lot of attention to this in the workplace and I've tried to mentor other women and encourage them. It makes a world of difference in an organization.

JAN BROWN: One study of college classrooms showed that some of the dynamics that go on when there's only one woman in the classroom change when 15 percent are women. You've got to get to the 15 percent. Well, as you just pointed out, at Motorola there's this isolation. There might be 15 percent of us in the whole corporation, but we're one here, one here, and one here. We don't get together as a group to affirm that someone else is feeling the same type of thing, and that makes an enormous difference in how you're coping.

I have done a lot of lecturing on women's issues. When I speak to both men and women, the men ask all the questions and the women are passive until the men leave the room; and then I can get them to talk.

BAUM: I do a lot of this kind of lecturing, too. That has not been my experience on college campuses, but it has been very much my experience in corporate settings. I spoke at an industrial plant where women came up to me afterward and said they were afraid to ask questions because their bosses were there and would be unhappy. I got calls at home. That plant has big troubles. It's interesting—in a university setting where people basically tend to feel much more independent, you

don't have that. You have the women not afraid to ask the questions and, in fact, eager to do so.

SHIMER: Another thing that happens in corporations is that women are expected to sit down and keep quiet. It blew my mind when I first started at Motorola. I was trying to learn my job, and I thought the best way to do this would be to sit quietly and listen at a couple of staff meetings to pick up what I could. And several of my co-workers came up to me and complimented me on the excellent way I'd started out in the company because I hadn't said anything! So I started talking to other women and found they were all getting this message to just sit down and keep quiet.

BENDZ: I can go one step further. They're not saying it directly but in the way they behave—whether it's language or aggression or sexual things, you're totally isolated from the conversation, even though you're in the room and have something to say.

BAUM: Do you think that happens on all levels? I'm on several industrial boards, for example, and at the board level I'm not really aware of that.

JAN BROWN: On a board, you are assumed to have a certain expertise or some reason for being there, and there's a certain amount of respect for that. But are the meeting dynamics between men and women on the board the same as they are in other places?

I would venture to say that they are a little more gentile, a little more subtle, but the dynamic is still there. How many women are on boards that you serve on, and what are the men doing when you speak? How many quit listening or start making notes or tune out? How do they regard what you've said? That's another issue. You can't tell right away about what's going on there.

BAUM: It's different for me because I speak very emphatically and very loudly, so people don't do that. But I know what you're saying. One of the young female faculty members at my own institution tells me that she's completely convinced that the fact that I speak so loudly and emphatically is a big factor in my success.

HALL: Do you speak in the same way at that Board of Directors meeting?

BAUM: You bet I do.

BENDZ: One thing that we don't do enough of is emphasize the qualities, the interpersonal skills, as well as the technical training, that a woman brings into a technical job.

SHIMER: Women uniquely bring a human side to engineering. At least I do. I feel that what I bring is good for men and women. By the way, the men who work in my organization feel that way and most of them never worked for a woman before. Any time you look at my staff, any staff I've ever managed, it's always more diverse than anybody else's staff because that's what I'm trying to do.

JAN BROWN: The people above you—are they recognizing the importance of what you're doing on this other level of human development? They can recognize that you've got a diverse group that's very productive in doing what it needs to do and they can think that you're doing very, very well. But do they reward that? Do they use that as a model for other workers?



'When engineers do wonderful things, they don't call themselves engineers anymore.'

PHYLLIS HALL, *IEEE staff executive*

SHIMER: No, not as much as I'd like to see.

SLOAN: Did any of you see the survey that came out recently where somebody studied men versus women bosses [see To Probe Further]? They had several criteria, and the women bosses were rated higher by their employees on all of them. The only quality that was close was delegation. It was astounding. I grew up in an era when the whole idea of a women boss was comical. People dreaded it whether they were men or women. Now we've come to a point where employees can experience both men and women bosses; and people, on balance, think that women do these things better.

BAUM: Women do this classic thing to themselves. I've read about it and I see it all the time with our students. If a man messes up an exam, he says, "The professor is unfair, what a lousy exam, he didn't prepare us for it." But if a woman does badly, she eats herself up with, "I didn't study enough, I knew I shouldn't have gone out this weekend."

HALL: That's not particular to engineering. It's a woman's way to be very hard on herself.

SLOAN: Maybe the woman's attitude is more responsible, but the man's reaction is more helpful for preparing for the next test.

ENG: Eleanor [Baum] brought up an interesting point. In this survey that we did, we asked, "What is the greatest obstacle in your career?" Without a doubt, for men, from age 19 to 91, it is always "The economy," or "Management doesn't understand; I have this brilliant idea." With women the No. 1 thing that shows up from the age of 19 to 29 is "I'm not good enough; I need more education," "I need more communication skills," or "There's something wrong with me."

JAN BROWN: It goes back to what I call water torture, because by itself, each little piece is not a big deal. But the accumulation of all the tiny little pieces keeps women in the position of always saying, "I'm not quite there, I'm not quite good enough."

I think women have a lot of expectations in college and actually at all levels that "I have to do well—if I say something, it's going to reflect on all women, so I can't ask stupid questions. I can't appear too dumb. If I don't know, I'd better go figure it out rather than ask."

BAUM: Do you think that the political movement of family values coming up strongly throughout the country is going to hurt the effort to make women think in terms of careers? I do.

BENDZ: I see women who are well-qualified and educated but who are not opting for a career.

SHIMER: I don't think it's just family values. It's been very difficult for women to make it in engineering, especially in industry where the isolation, the water torture, makes it difficult for them, particularly early in their career. They want to fit in. They don't want to be identified with

other women and they become isolated. They don't realize that other women are facing the same kinds of issues.

For years with the feminist movement, women thought that a career was a good option. So it was worth a little pain to stick with it and do whatever it took to be successful. That helped women get over the potential energy barrier. Now there's another option. It's okay again to say, "I want to stay home and raise my children." And I agree with that, by the way. But there was no respect for that then and I'm not sure there is now. It's just words. But if there is respect for it, you're going to see women opting out of a career because it's so difficult.

JAN BROWN: Your point about fitting in is exactly the water torture I was talking about, because you feel bad no matter what. Either I make myself a buddy and try to be acceptable to the guys or I just want to be invisible and blend in. If I want to stay in that environment, everything I do makes me feel bad. Why wouldn't I opt to do something easier?

ENG: You're talking about instilling insecurities—from the time the young women are about 12 or 13. It culminates in the first year after graduating from college. A lot of young women don't know what they want to do. At about age 26, they all get worried because they are not married. "I have to have children. What am I going to do?"

JAN BROWN: I consult with high-tech companies in the Austin area concerning recruiting and retaining women engineers. These companies get them in for three years and then they're gone. They're leaving the profession. They disappear because it's easier, and I think it's the water torture. The environment, as you said, instills insecurities. It's just a little bit every day, every day and they find that they're not happy. If they have a choice to go do something else, they're leaving and doing it.

Family matters

BAUM: Do you think women are made to feel guilty in a corporate setting about affirmative action legislation? Is there an attitude, perhaps, that men are here because they're good, you're here because you're a woman? Someone who's a minority is here because she's a minority and the men are better?

JAN BROWN: It doesn't matter that men are good. They can be not so good, but they are here because they have to support their families.

ENG: I know a woman engineer whose husband worked on commission as a salesman for a pharmaceutical company. She's been at a large defense contractor for 17 years. The company was doing massive layoffs, and they actually had the nerve to call her into the boss's office and say, "The reason we're laying you off is because your husband is working and you can go back to graduate school."

BAUM: That's not even legal. How could they possibly do that?



'I have a problem with American corporations that say they want to be in the '90's and they don't have spousal hiring assistance programs.'

JULIE SHIMER, *Motorola vice president*

JAN BROWN: That is grounds for a lawsuit.

SHIMER: Companies are made up of people who don't know the letter of the law. I know that's true. They don't think about what they say. They're asking what they think are innocent questions, but they have all kinds of tags. They ask, "Do you have kids?" Don't ask me that question! They're trying to be friendly, but they don't understand that sends a signal. It's a flag they're raising to a female that says, "This is going to impact your job description."

JAN BROWN: Right. Because if I have kids, I'm going to be taking time off to take care of them, even though I may have someone already taking care of them, or that's my husband's job to do.

ENG: The statistics in the survey we did compared men and women with the same length of career, at roughly the same managerial level, the same salary, and the same number of kids. On the average, the women took off a total of 23 months more than the men did—for whatever reason.

BAUM: Well, you're talking about maternity leave and things like that?

ENG: Maternity leave is in there and other significant chunks of leave.

JAN BROWN: A company I was dealing with in Austin has a personnel policy that allows both men and women to take time off for kids, whether it's because they're sick or for parent help day or whatever. The men don't take the time off, the women do. The men feel that it's going to affect their career and the women know the kids have to be taken care of.

BAUM: I had done a survey, too, in '89, of working women engineers. The women who responded felt that in doing housework their husbands were equal partners, but in child rearing, it was still primarily the woman's responsibility.

HALL: The key word to me is responsibility, because men do these things at their own pleasure, when it's necessary, when it doesn't interfere. The women have the responsibility, so whether they want to do it or not, they pick it up.

On the other hand, I do see men struggling with this much more overtly because they want to be more of a parent. A lot of young men who have young babies do want to do more fathering.

JAN BROWN: Is the expectation still that it's going to inhibit your career if you take that time off?

BAUM: Yes, it's a reality. It does inhibit your career.

JAN BROWN: And it's much more difficult for guys to make that decision than it is for the women, because the assumption is that it's the woman's responsibility to take care of the children, anyway. So even though women know it's going to hurt their career, they have this responsibility; and the guys—yeah, it's sort of their responsibility, but there's someone else who can do it, so they move in the other direction.

SLOAN: As long as electrical engineering is so male-dominated, many managers have the attitude that "If you work for my company, you work for it 12 hours a day and weekends." Women are willing to do that during the early years. But right about the time they get serious about having children, that's not what they want to see. They don't know what to do when they come up against that. So, there's an

issue of what can be done in the area of family-friendly policies.

ENG: Talking about family-friendly, if we compiled a list of which companies offer which benefits and published it, people would self-select, thereby forcing other companies to have better benefits because all the good people were going to the companies with the best benefits. But nobody ever wanted to do it. Maybe there were too many legal problems.

BAUM: What happens with relocation? Are women still the ones more likely to move when their husbands get relocated? Because it's my perception that it's the woman who compromises more in those situations.

SHIMER: This is my pet peeve. I have a problem with American corporations that say they want to be in the '90s and yet don't have spousal hiring assistance programs. I'll tell you what—it's tougher for women to relocate to a new job. I've just made a move, and my husband moved with me. God bless him, I love him for that.

About 100 percent of married women have a working spouse, while about 50 percent of married men have a working spouse. So that's why it looks like a woman's issue, but it's not. This is the '90s, and most couples are working couples. Then why the heck can't corporations get together in the community and help place the other spouse? The biggest relocation issue is whether the accompanying spouse is going to have an opportunity to get a meaningful job that can be used as some kind of a career path.

JAN BROWN: Companies aren't addressing the issue, but universities are good at recognizing that there's a spouse that they need to try to find a job for.

BAUM: Jan, I don't think universities are good at it at all. They recognize the issue because, in a university setting, the number of female faculty has increased—not necessarily very much in engineering, but on the campus as a whole. It's a difficult issue because a lot of universities are uncomfortable having a husband/wife team within the same department. Some are uncomfortable even having a husband/wife team within the school of engineering, and whether it's legal or a policy issue—those are realities. Another reality is that a lot of universities are located in university towns where there's a large cadre of well-educated women and no jobs for them. That's a big problem in many families.

APRIL BROWN: I would like to add a positive note. I've been married twice, to electrical engineers, both with Ph.Ds., and in the same field as me, semiconductors. I've worked for Hughes Aircraft and they have been extremely good in placing both parties. I've seen that they tried to do that with other people who were hired into the company.

Georgia Tech has gone out of its way to hire spouses. They realize that in many cases women Ph. Ds. are married to men with Ph. Ds. They were pro-active in asking me if I needed any help in placing my spouse. In fact, with respect to husbands, I have to give mine some credit here. He's moved with me. We've decided that we're helping to support my technical career, so he has made some decisions and choices on that basis and does more parenting right now than I do.

ENG: Hang on to that one.



'When equal employment opportunity became a hot topic and affirmative action was the new thing, sexism and discrimination went under the table.'

PATRICIA ENG, *U.S. commission officer*

Harassment questions

SPECTRUM: Let's talk about harassment and women not having any recourse. What should women do? What can they do?

JAN BROWN: Remember that when it comes to overt harassment—overt actions and behavior—we're talking about 5 percent of men. It's a small percentage, but we have got to have tools for dealing with it.

HALL: But it is quite pervasive. And perhaps that small percentage makes it seem that it isn't wider spread. So we're not able to ferret it out.

JAN BROWN: Then there's also covert sexism and that is perpetrated by everybody—men and women. It's important to say that women do it ourselves, like the way we say, engineer "he" instead of engineer "she."

ENG: My mother, who was in human resources at a pharmaceutical company, noted that when equal employment opportunity became a hot topic and affirmative action was the new thing, sexism and discrimination effectively went under the table. And people who behave that way became more talented at calling it something else and making it more subtle. How do we handle the covert stuff?

It's easy for me to tell young women what to do if somebody says, "You have nice legs." But what do you do with someone who says, "Gee, you must have spent a little more time blow-drying your hair this morning." How can we help the youth, the 19- through 25-year-olds, until they get strong enough to turn off the water torture?

JAN BROWN: Water torture never gets turned off. The question is whether they have the wherewithal to turn it in a different direction.

ENG: But how do we help them deal with these subtle things? I used to think that it always happened to somebody else; and it took me three years to realize it was happening to me. It was so, so subtle.

JAN BROWN: A big part is that we talk about what covert sexism is. "Nice work for a woman"—well, that carries a double meaning. That's the water torture, the covert piece. He's saying she did a great job, but he's uncomfortable with the fact that she is a woman, so he adds this other little piece as a joke. But he needs to understand that it's not a joke and that it undermines her self-esteem.

She needs to recognize that when she hears stuff like that, she should get it clarified. "Say, what do you mean by that? Do you mean that I've done a good job for anyone in the group so we can take away the last part, or were you just kidding?" But you have to choose your battles. You can't respond every time someone says that. But if you're conscious of how that could affect you, you can choose whether you will deal with this guy at this time or just let it roll on by.

SHIMER: I don't know about you, but when I realize I've been put down because of my gender, I want to bite somebody's head off. It's not a time when I can sit down and say, "What did you mean by that?" What I've learned is just

to say, "Excuse me?" It's a self-learning tool because if what they said was offensive, they will not repeat it out loud. But they'll think about the fact that it was offensive and they may not say it again.

A lot of times discussions are really not productive because some women will be in tears when they're angry, and that's not going to help the cause. So that is something that can be said right away, which you can learn as a reflex reaction. Then later on you can go back and have a discussion about what you were feeling.

JAN BROWN: There's another aspect, too—by being silent, we are then covertly accepting what's being said.

ENG: Passive consent. Inviting the person to do it again.

JAN BROWN: Exactly. And it's our duty to speak up, even if it's not directed at us individually.

SLOAN: Even more so, because we can do it a little more objectively.

HALL: But we have to recognize that it is not always offensive to everybody, depending on who said that about the blow dryer, for example. So we shouldn't categorize statements like "Hey, you look nice today" as being only something that we would reject out of hand and be offended by.

SHIMER: We have to be fair because men are confused by this issue. One man can say certain things to me because outside of work we're friends, but someone else can't. I remember in my early days at Bell Labs, men were confused by this. We needed to start saying that the person who defines harassment is the person who's hearing it, and it matters.

There needs to be open dialog. I think the worst thing is silence. It was interesting to me that after men started to get the idea, they would be pulling other guys aside and saying, "You have to be careful about making a remark like that, it may not be appropriate." It was changing the culture. It became a much more positive work culture and the underground sexism and harassment were starting to dissipate.

APRIL BROWN: I'm a little worried about the statement that silence implies passive consent. It puts the burden on the woman, so to speak. If you're silent because of other factors, fear being one of them, it might be construed in your mind that it was your fault.

SHIMER: You have to be careful because it can be taken that way. Some women feel they're responsible for the harassment they are taking—that they deserve it somehow. The best defense is a good offense, attacking this underlying culture where sexism, discrimination, and harassment have gone underground—which is typical of most companies these days because of the fact that it's politically incorrect.

JAN BROWN: Overt stuff there are laws against, but we don't know how to legislate against this covert stuff.

SHIMER: When it comes to changing the cultural environment, this is what I try to convey to my management. "No. 1, put a woman on your staff, because you don't have anybody to tell you what women are thinking." The woman at the bottom of the organization is not going to come into the boss and tell him what her boss is doing because of the fear factor.



'When it comes to overt harassment—overt actions and behavior—we're talking about five percent of men who perpetrate that.'

JAN BROWN, *technology consultant*

I tell them, "You have to mentor a woman that's not in your department, so you get the perspective. You need to sponsor a woman that does work for you. You know you sponsor men, so sponsor a woman. Pick one and bring her up. You need to diversify teams."

One thing that happens a lot is a subtle form of discrimination. Affinity groups tend to be work teams. "I like to work with people like me, so I don't have women, I don't have minorities on my team." There are two bad things about that. In a culture where teamwork is valued, then certain groups are excluded from doing that valuable work. The other thing is that the teams themselves are lousy because they don't get an opportunity to get different viewpoints. They just aren't as productive or creative.

The fifth thing I told them was to give women international assignments. Every global company I've been in has been reluctant to put women in another country for all the reasons that we were describing earlier. But we've just got to face that head-on and get them out there, because in my company, if you don't get an international assignment, there is a ceiling. You can't get above a certain level without having had that.

I told one group manager that he could change the culture in his organization in one year if he did that. Interestingly enough, he's sort of moved forward with the challenge. He hasn't yet put a woman on his staff, but his staff has. He put it in their performance plan!

APRIL BROWN: Hopefully, when they're diversifying the groups, they can try to have a critical mass within the team so that the women aren't split up too much.

SHIMER: Right. Motorola is making an overall effort to increase the numbers. I think the numbers are everything, because without numbers there is isolation. And if you don't have representation at all levels of the organization, then there is an information gap. You have a culture that allows that kind of stuff to go on and nobody who can change it hears about it. I used to give a little speech that defined sexual harassment when I was at AT&T. I did it first for my own department because I was so frustrated with the harassment going on there. I wound up giving it about 10 times.

I said, "Say you are bald." (This guy helped me out with this because he was self-conscious about going bald.) "And every time somebody sees you in the hall, they tell a bald joke. Now, you know, there's nothing really wrong with telling a bald joke, but if every time anybody sees you, they tell a joke about bald people, after a while you're not looking forward to going to work anymore because you know you're going to have to take that rubbish."

The general unhappiness factor of wom-

en when we go into work is high already. Then the stuff that everybody else has to put up with just gets piled on top. My bosses were saying, "Women are usually discontented, they move around more." Yeah, that's because we have to put up with the gender bias in the environment. Women take that all the time. The guys who listened to my speech could get this. Then I gave them all kinds of specific examples of what had been said and done. These men were shocked that it was going on. If they knew about it, they would have put a stop to it. But they just don't get to hear about it because women are afraid to say anything.

JAN BROWN: It's just the undercurrent of how you're looked at. People don't have to say a thing. It's how they look at you. How many times have you wished you could walk down the hallway and get eye contact with someone above breast level? It's just impossible for some people to do that. Or they just look at your legs. And telling bald jokes is an overt thing like always telling kitchen jokes. Same kind of thing. Over and over it's the water torture. You have to wonder. If you let it go, it's no longer fun to go into work anymore. And it really works to undermine your self-esteem.

SHIMER: Even if you decide to fight it, then you have that hassle. I'm always the one trying to educate them. Why the heck can't they go off and get themselves educated?

SLOAN: There are some other things that are just simple that we were talking about a few minutes ago, about how it's better when you get the culture to the point where the guys do it. For the longest time within the IEEE, my pet peeve was people who would address boards of directors or some other committee I was on as "gentlemen." Even when the board of directors got to be four women, it was "gentlemen." It's just the noninclusiveness of it. I don't even want to fight that directly. But just in the last couple of years, I've noticed that some of the guys will make that correction. It's really a step up.

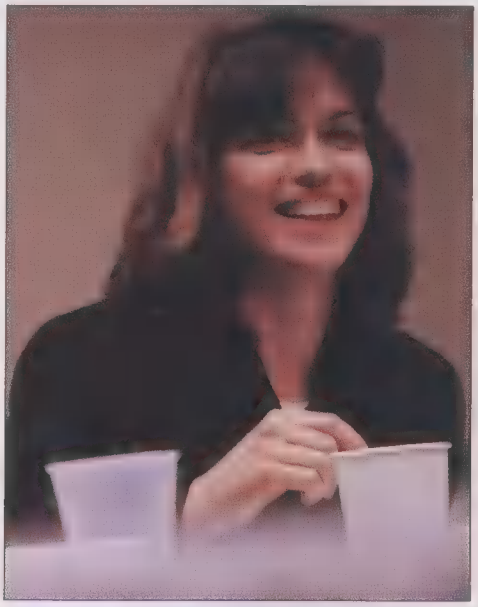
JAN BROWN: It's everybody's responsibility to examine his or her behavior—women as well as men. I have to consciously monitor my own thinking. Do I say engineer "she"? If I don't do it in my own mind, how can I expect my male colleagues to be doing it? Am I more likely to talk to a male or a female salesperson, depending on what I'm buying? Am I more confident talking to the guy because he's the nerd and knows the specs?

APRIL BROWN: I agree. And once you examine your own unconscious thinking and your own behavior, there's positive feedback because your self-esteem is improved. You have the confidence and ability to take on interactions with other people and try to set them right about how you're treated.

JAN BROWN: Then guys start that thinking process, too. Then they can speak up and be on our side. Because I think 99 percent of them are.

Tools for survival

ENG: We've been doing a lot of soul searching on issues that we've all experienced. But what should we be telling the young women engineers fresh out of school? It isn't all bad because we're all here and we're excited about our careers. What's the good side? What can we tell the young ones so that when they get to age 26, they don't decide they are going to get married, have kids, and leave the profession?



'When you participate as a volunteer in the IEEE or in another professional society, you are limited only by your own efforts.'

APRIL BROWN, *associate professor*

JAN BROWN: They have made it that far because they like doing the engineering. I think that's self-evident to them. They leave because while it's fun to do the work, it's not fun to be in that environment. What we can do is help make them aware of the underlying sexism so they will know how and when to choose their battles. Help them let the distasteful stuff flow on by them and know what they have to do. Help them find mentors.

SHIMER: I'll bet every one of us can identify a person who helped us get over the hump, stay in the profession, and really get excited about it. Two or three people in my career—both men and women—have done that for me. Those of us who are more senior should be mentors.

JAN BROWN: And we should tell them to network.

SHIMER: Right. At every level.

JAN BROWN: Not just with women, but with men, too. But it's important that they not let themselves become isolated. They need to go find the other women.

ENG: Earlier we were talking about how many of the young women choose not to network, and instead isolate themselves. What would you propose for those, because those are the ones that are going to drop out?

SLOAN: Do you really feel they choose to isolate themselves or not to network, or are they just not aware of the opportunities?

ENG: The women that I've run into are Society of Women Engineers members until they get their first job. Then they disappear off the planet. They say, "I don't need a society anymore. I've made it. I've got my job." And you watch the attitude tail off. By the time they're working for five years, they are disenchanted and upset and still don't want to network. What can we do?

SHIMER: We need to tell them that this is what's going to happen. You really must not isolate yourself. A lot of times people don't know what the opportunities are. They need to know there is a positive benefit from networking with other women. Somehow it takes women longer to make this connection. If I don't want to hang out with other women, why would other women want to hang out with me, or why would men want to hang out with me?

We distance ourselves. This is the queen bee syndrome at every level. We distance ourselves from other women because we don't want to get slimed by the impression the profession has about women. But we're women, so we can't deny it.

SPECTRUM: How do you find a mentor? You can join an organization, the Society of Women Engineers, for example; or get involved with activities of the women engineers in the IEEE. Are there other ways?

JAN BROWN: Even within a corporation, just seek out the other women who are there.

ENG: I remember once walking up to the second-highest ranking woman in

my company (and I was shaking in my shoes). I just said, "I think you're really terrific and one of these days I hope that I can do what you're doing."

She said, "Oh, yeah? Come on up to my office." It was that easy because it's very flattering to have somebody want to come and talk to you.

JAN BROWN: Male and female!

ENG: Yes.

JAN BROWN: Everybody likes people to come to them and ask them stuff, it makes us all feel good. And men in companies will go that extra mile if you approach them first. They might be too shy to say something to you first lest it be seen as sexual harassment.

ENG: You've got to do a little homework. This person looks like a great person and you find out three weeks later he's the biggest Casanova in the entire company. You do have to do some checking around. So you ask the other women.

SHIMER: But it's so important to network because that makes a lot of this environmental harassment easier to take. A lot of women think, "It's just me." And then they realize that others are having similar experiences.

BENDZ: I hope we don't lose sight of the fact that there's a responsibility that we each have as a professional, and that's the toolbox of professional activities that you can go out and do all by yourself, without a mentor, without a network.

SPECTRUM: What is in that toolbox of yours?



da Geppert

'A man considers engineering to be a career. But a woman—to be successful—must also consider it to be a crusade.'

LINDA GEPPERT, Spectrum *associate editor*

BENDZ: Patents. Publishing. How-do-you-do types of things.

JAN BROWN: Individual responsibility, not just for professional but also for personal behavior. I think that's it. Another thing on that list is being conscious of sexism and how it affects you. There's so much unconscious stuff going on, we need to make that conscious.

SHIMER: I didn't hear "professional society activities" in there, but I think it is important to be active. Take some role in the IEEE if you are a member because that's the best way to make connections. You should be submitting papers at conferences, because when you speak at a conference, everyone comes and talks to you. If you go to a conference and don't have a paper, you've got to be running around trying to make connections with everybody else. If you take a job as an associate editor (of a society publication) or as an officer in your Section or whatever, it gives you an opportunity to network.

ENG: If you take on any role of leadership, even if it's at the Section level or Committee level, you are going to develop skills and knowledge and networks simply because of your involvement with your society. It's incredible networking. There are people who are stars in the engineering field and it's only through society activities that you get to meet them.

APRIL BROWN: When you participate as a volunteer in the IEEE or in another professional society, you are limited only by your own efforts, by what you put into it. It's a great opportunity. ●

To probe further

The 1993 edition of the National Science Foundation's biannual *Science & Engineering Indicators* contains information on engineering education and employment. It is available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402; ask for Stock No. 038–000–00589–8.

A source for worldwide employment figures and related information is the OECD Publications and Information Center, 2001 L St. N.W., Suite 700, Washington, DC 20036–4910. Data on U.S. employment is also available from the Bureau of Labor Statistics, Postal Square Building, 2 Massachusetts Ave., N.E., Washington, DC 20212.

A study on management and leadership skills of male and female managers was conducted by Lawrence Pfaff and Associates. For more information, contact the company at 3506 Lovers Lane, Kalamazoo, MI 49001.

The Society of Women Engineers (SWE) has published the results of its survey on gender differences in engineering. Copies of the report may be obtained from SWE headquarters, 120 Wall St., 11th floor, New York, NY 10005–3902. SWE is a nonprofit organization that assists and supports women engineers and informs the general public about women engineers and their achievements. The society is open to engineers and computer scientists, both men and women.

The IEEE Women in Engineering Committee is developing ways to support and encourage women engineers. A newsletter and World Wide Web home page are in the works. The committee can be reached by sending e-mail to `Women@IEEE.org`.

The International Network of Women in Technology, or WITI, was founded in 1989 to encourage women engineers and scientists in their career advancement. WITI will host the Women in Technology Conference on June 27–29 at the Santa Clara Convention Center in California. Gloria Steinem will be the keynote speaker. More information may be obtained from WITI at 4641 Burnet Ave., Sherman Oaks, CA 91403.

There are several useful World Wide Web sites available to those who have access to the Internet. A list of organizations for women scientists and engineers can be obtained at `gopher://www.cs.yale.edu:/hGET%20/HTML/YALE/CS/HyPlans/tap/sci-women-groups.html`. General information on and resources for women are available from the women homepage at `http://www.mit.edu:8001/people/sorokin/`. The Society of Women Engineers' homepage can be found at `http://www.thesphere.com/swe`.

The discussion group Wisenet focuses on education and employment of women in science, mathematics, and engineering. To sign up, send an e-mail message to `listserv@UICVM.CC.UIC.EDU`, no subject, with the message "`subscribe wisenet first_name last_name`".

To handle small, power-hungry electronic systems, researchers are exploring air and lithium electrodes and solid electrolytes

THE SEARCH FOR BETTER BATTERIES

JUST ABOUT EVERYONE HAS HEARD of Moore's Law, which (in its current form) states that the number of transistors in high-volume, state-of-the-art integrated circuits doubles every two years. But no one has ever seen a comparable statement about batteries—and for good reason. For if such a battery law were written, it would more closely resemble the equation of motion of a glacier than anything in the world of semiconductor electronics.

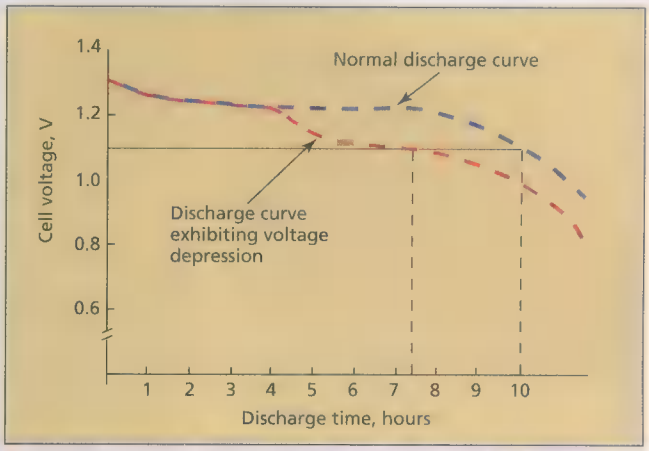
What makes the contrast painful is that Moore's Law has now operated long enough to bring us computers, advanced cellular telephones, and other products small enough to be carried around and, in some cases, even held in one hand—ideal products, in other words, for battery-powered operation. But these devices demand a fair amount of power, and batteries have not grown in capacity at anything like the rate that they require. As a result, the run time for such wonders as laptop computers is disappointing, to say the least.

Travelers would like their laptop machines to run for a full working day—or better yet, a full week on the road—between charges. But most such computers today are supplied with rechargeable batteries that give them an advertised run life of about 4 hours and a real life of about half that.

To mend matters, manufacturers of rechargeable batteries are exploring at least five technologies: nickel-cadmium, nickel-metal hydride, lithium-ion, lithium-polymer, and zinc-air. The venerable lead-acid battery is also still very much with us. In its sealed form, it could certainly power portable electronic equipment, but it is too heavy for powering most hand-held items because of the technology's fairly low specific energy [see table on p. 56].

On the other hand, their low cost, low rate of self-discharge, and the fact that they can be float-charged for long periods without harm to their performance give lead-acid batteries great appeal for standby applications. This is especially the case when lots of energy must be stored, in uninterruptible power supplies and portable medical equipment like defibrillators, for example.

Alkaline cells are likewise available in rechargeable form nowadays (witness the Renewal cell from Rayovac Corp., Madison, Wis.), but their low specific power and short cycle life have on the whole limited them to uses traditionally served by primary cells. (Although it can be recharged some 25–50 times, the Renewal cell has specifications much more typical of primary cells: a low self-discharge rate and a high energy capacity on the plus side, and on the down side, inability to deliver nearly as much power as other secondary cells.)



ILLUSTRATIONS: MORRIS KHAN

Despite the voltage depression [lower curve], the full ampere-hour capacity of a nickel-cadmium cell can be realized, albeit at a reduced voltage. For the many applications that require the battery's rated voltage, the reduction does represent a genuine loss of capacity. Note that the phenomenon manifests itself only after the cell has been partially discharged; it probably begins when most of the free cadmium has been used up and the intermetallic phases begin to dominate the reactions at the negative electrode.

By far the best established rechargeable battery for portable applications is the nickel-cadmium type. It has a positive plate of oxidized nickel (actually, the active material is nickel oxyhydroxide), a negative plate of cadmium, and an aqueous solution of potassium hydroxide (KOH) for the electrolyte. It can endure a lot of abuse physically and electrically, and it has an impressive specific power rating. Its robustness and ability to deliver very high currents for short intervals or moderately high currents for longer periods make it the battery of choice for equipment like power tools and some portable electronic instruments. Also, because the alkaline electrolyte does not enter into the discharge reaction (as the acid does in a lead-acid battery) and, hence, get depleted as the cell discharges, Ni-Cd cells can deliver nearly as much power near the end of a discharge cycle as they can when fully charged.

So what's wrong with NiCds? Five things mainly: one is that they suffer from the memory effect, a phenomenon that burdens the user with having to, at least occasionally,

MICHAEL J. RIEZENMAN
Senior Editor

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Defining terms

Anode: the cell plate, or electrode, at which an oxidation reaction occurs. A cell's negative electrode is an anode when the cell is discharging, but a cathode when it is being charged. Possibly, therefore, the terms "positive" and "negative" may be more useful in identifying electrodes.

Battery: two or more cells connected to form a single unit. (Since contemporary usage allows for one-cell batteries, the terms "cell" and "battery" are sometimes used interchangeably.)

C-rate: a rate of charge or discharge in amperes numerically equal to the capacity of the battery in ampere-hours. Multiples and submultiples of the C-rate are commonly used. For example, the specific energy of a battery is often specified for discharges at the C/3 rate.

Cathode: the cell plate, or electrode, at which a reduction reaction occurs. A cell's positive electrode is a cathode when the cell is discharging, but an anode [see above] when it is being charged.

Cell: an electrochemical energy-storage device consisting of two electrodes, or plates; an electrolyte; and (usually) a separator.

Electrolyte: the ionic conductor, typically a liquid, that provides the internal connection between the plates of a cell. The electrolyte must not be an electronic conductor lest it short-circuit the cell.

Life: the total length of time that a battery will operate before it needs to be replaced. For primary batteries, it is expressed in hours of actual use; for rechargeable units, the limiting factor is the number of months or years since the battery was manufactured or the number of charge-discharge cycles to which it has been subjected (cycle life).

Energy density: the volumetric energy storage density of a battery, usually expressed in watt-hours per liter.

Float charging: the practice of keeping a storage battery ready for use by means of a continuous, long-term, constant-voltage, limited-current charging regime.

Memory effect: the reduction in capacity of a nickel-cadmium battery due to repeated partial discharge–charge cycles.

Power density: the volumetric power density of a battery, usually expressed in watts per liter.

Primary cell: a cell that can be discharged only once.

Secondary cell: a rechargeable cell.

Separator: a nonconductive porous material inserted between the plates of a cell to keep them from shorting together. Although itself nonconductive, the separator must be permeable to the electrolyte solution so that ionic conductivity is maintained between the plates.

Specific energy: the gravimetric energy storage density of a battery, usually expressed in watt-hours per kilogram.

Specific power: the gravimetric power density of a battery, usually expressed in watts per kilogram.

follow a time-consuming recharging regime in order to maintain their rated capacity. NiCds also store only slightly more energy per unit weight than lead-acid units, have a fairly high rate of self-discharge, and cannot (or should not) be recharged at high temperature. Worst of all, cadmium is an awful poison that can contaminate the environment when worn-out batteries are mixed with household rubbish and incinerated. (In fairness, it should be pointed out that all batteries contain toxic substances; none can rightly be described as environmentally benign. But cadmium, the experts seem to agree, is in a class by itself.)

No thanks for the memories

The memory effect in nickel-cadmium batteries refers to the decline in their effective capacity with repeated partial discharge-charge cycles. That is, if a Ni-Cd battery is repeatedly recharged after being discharged to, say, the 60 percent depth of discharge point, it will eventually become incapable of delivering more than 60 percent of its rated capacity—at least at its normal output voltage. This condition can be corrected to a degree by putting the battery through one or more complete charge-discharge cycles; however, it may not be possible to restore the battery's original capacity.

Interesting to relate, battery experts disagree about why the memory effect arises. A significant minority blames the nickel plate, of which more anon. But what appears to be a majority believes that the effect is associated with the cadmium electrode. In particular, it is associated with cadmium electrodes fabricated on a sintered nickel base. Since the industry has largely switched to bases of nickel foam or fiber, the problem is less serious than it used to be.

Although some details remain unclear and laboratory simulations have proven difficult to reproduce, the effect appears to be due to the growth of abnormally large crystals on the cadmium electrode. These large crystals reduce the surface area of the electrode, thereby increasing the cell's effective internal resistance and hence the voltage drop during discharge. Because of the increased voltage drop, the end-of-discharge voltage is reached prematurely in the discharge cycle, reducing capacity.

Crystal growth is hastened by charging the battery with low currents and at raised temperatures, as well as by repeated partial discharge-charge cycles. This leads to a related phenomenon, called voltage depression, in which the capacity of a nickel-cadmium battery is reduced by prolonged trickle charging, as may happen when the batteries are used in, say, emergency lighting systems.

Some authorities feel the true memory effect is associated with large crystals and that voltage depression has more to do with the formation of intermetallic compounds of nickel and cadmium in the cadmium electrode. Other electrochemical effects have also been cited. Whatever the cause, the result is the same—a drop of about 150 mV per cell, resulting in reduced capacity [see figure on p. 51]. Deep discharging and then recharging at not too low a current and not too high a temperature cures both effects by destroying the large crystals as well as the intermetallic compounds.

Nickel-metal hydride

The unpopularity of cadmium, all the same, encouraged the development of an alternative: the nickel-metal hydride (Ni-MH) cell. As luck would have it, Ni-MH batteries are not only cadmium free, but also can store more energy than comparably sized Ni-Cd units. On the down side, they deliver less power, have a faster self-discharge rate, and are less tolerant of overcharging.

Like the Ni-Cd cell, the Ni-MH unit employs a nickel positive electrode and an aqueous KOH electrolyte. The main difference is that the active material in the negative electrode is hydrogen absorbed in a metal alloy. Since the metal-hydride electrode has a higher capacity per unit volume than cadmium, it may be smaller in size, leaving room for a larger positive electrode, and hence a greater battery capacity.

The key to the characteristics of the Ni-MH cell is its negative plate—the metal alloy in which the active hydrogen material is stored. Manufacturers each have their own proprietary formulation for these alloys, but the materials still fall into two general categories: those based on mixtures of nickel and rare earths, and those based on nickel blended with titanium, vanadium, and zirconium. The second group yields superior energy storage density, but the industry seems to be favoring the first because it is better able

to hold onto hydrogen, thus lowering the self-discharge rate.

The negative electrode is the clue to most of the strengths and weaknesses of the Ni-MH cell. With regard to specific power, for example, the technology has suffered in comparison with Ni-Cd. One reason, according to Frank McLarnon, staff scientist, Lawrence Berkeley Laboratory, Berkeley, Calif., is that heavy discharges or charges can heat the metal-hydride electrode and change the special structure it must have to hold onto its hydrogen.

Recently, he points out, improvements in the negative plate have allowed the industry to build Ni-MH cells with specific powers above 230 W/kg at full charge. Nonetheless, 80 percent depth of discharge is the condition under which specific power is often specified, and there, numbers on the order of 130 W/kg are more typical.

Charging differences

Charging Ni-MH and Ni-Cd cells is similar insofar as both employ modified constant-current regimes. But while the charging reaction for Ni-MH cells is exothermic, Ni-Cd cells actually absorb heat during charging. For that reason, until the very end of the charging cycle, the temperature of a Ni-Cd cell does not rise. Neither does it go down much, because ohmic losses generate a little heat, which pretty much cancels the endothermic nature of the charging reaction. The cell will heat up if the charging current is not reduced when it becomes fully charged, but the temperature levels off at reasonable charge rates, according to David Linden in his chapter on sealed nickel-metal hydride batteries in the *Handbook of Batteries* [see To Probe Further].

In a Ni-MH cell, by contrast, the temperature continues to rise, so that accuracy in sensing when charging is complete becomes more important. This is especially true when charging is done at high rates. Otherwise, the temperature might increase to the point at which it damaged the metal-hydride electrode and diminished the cell's capacity.

In fact, the pressure rise inside the case of a Ni-MH battery may also be used to sense the point at which charging should end, observed Philip C. Symons, a battery consultant and principal of EECI, Morgan Hill, Calif. It works with larger cells, he told *Spectrum*, and the technique may be easily applied to smaller ones. Valves penetrating the battery case are not needed, he emphasized; a simple strain gage on the outside of the case will do.

What will not do is simply to cut off the charging current after a fixed length of time, as is a common practice with Ni-Cd batteries. Actually, Symons pointed out, that approach is a bad idea with any kind of battery except possibly when rather low charging currents (C/10 rate and less) are used. For Ni-Cd batteries, the preferred control method is to use the rather sharp rise and then drop in cell voltage as a signal to terminate charging. (The rise occurs as the cell becomes fully charged, and the drop is due to the onset of oxygen recombination at the cadmium plate.)

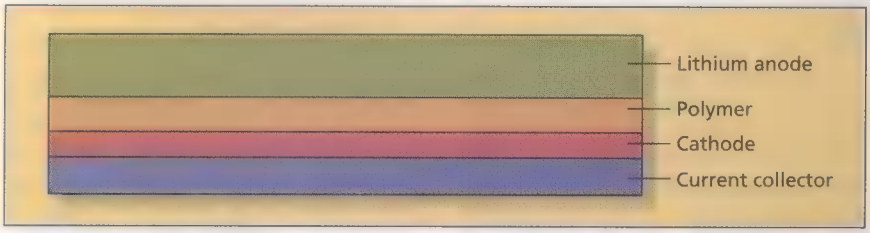
Unhelpfully, although Ni-MH cells exhibit similar behavior, the voltage peak is less pronounced and cannot be reliably detected by low-cost circuitry. The recommendation here is to monitor the battery temperature and to cut off charging when a specified rate of temperature increase is reached.

Just monitoring the temperature is insufficient because ambient conditions vary. Measuring the temperature rise above ambient is better; but as the allowable rise is a function of several variables (cell size, number of cells in the battery, and so forth), the cutoff temperature rise is different for each battery type. The rate-of-temperature-rise criterion does away with these ambiguities and is consequently the method to use for longest battery life. (Actually, in most practical systems, multiple criteria, logically ORed together, are used: charging is terminated when any of the criteria is met.)

A recurring question about nickel-metal hydride batteries is, "Do they exhibit a memory effect?" Some experts feel that the memory effect is, by definition, a cadmium-related phenomenon and that no battery without a cadmium electrode can have it. Those who would inculpate the nickel electrode argue that some form of voltage depression does occur with Ni-MH cells when they are subjected to repeated partial discharges and recharges.

Manufacturers of Ni-MH cells contacted for this report said that they have never known it to occur with their products. Even those others who asserted that it does exist admitted that it is a minor phenomenon and that most users of sealed Ni-MH cells will never experience it.

The one point on which all agree is that all sorts and conditions of battery and equipment failure get lumped together and labeled "memory effect"—even when those problems have nothing to do with it. Thus, a loss of capacity due to undercharging, overcharging, self-discharge, or exposure to high temperatures is often mistakenly attributed to memory effect.



In a lithium-polymer cell, the polymer electrolyte must be kept very thin (≈50 μm) because of its low ionic conductivity. The cathodes of such cells are typically based on transition metal oxides and are backed by a metal-foil current collector. The polymer layer also serves as a separator.

The promise of lithium

While Ni-Cd and Ni-MH batteries undoubtedly improve on their lead-acid and Edison (nickel-iron) predecessors, they are hardly the last word in energy storage. As has been noted many times in many places, the trouble with all batteries—both primary and secondary—is that they store less energy per unit weight or volume than users would like. They do much better in that regard than capacitors and conventional flywheels, but nowhere near as well as hydrocarbon fuels, to take a rather unfair example. The problem is twofold. First, only a fraction of a battery's mass is made up of active material; the rest adds weight but no energy. Second, the active material itself often has an unimpressive energy-to-weight ratio.

Dealing with the first problem is a matter of clever engineering and design. Lead-acid batteries, for example, improved over the past few decades when most of the industry switched from fairly heavy hard rubber cases to lighter plastic ones. More recently, the Horizon battery, a lead-acid unit for electric vehicles, achieved a specific energy of 42 Wh/kg and a specific power, at 80 percent depth of discharge, of 240 W/kg. The Horizon, which uses plates woven of lead-coated glass fibers, uses only 30 percent as much lead as storage batteries with cast lead plates. In effect, it replaces the structural lead of a conventional battery with lighter, stronger glass. According to the Horizon's manufacturer, Electrosource Inc., Austin, Texas, the woven plate technology is now being adapted for use in smaller batteries as well.

Handling the second problem appears still simpler: run your eye over a table of the elements, see which one has the best combination of high electrochemical potential and low equivalent weight, and turn it into a battery. With that in mind, scientists have focused on lithium—the lightest

and most reactive of metals—for batteries to power all sorts of things from hand-held devices to electric cars.

In reality, of course, building such batteries is far from simple. The most daunting of the problems are the reactivity of metallic lithium and its tendency to grow dendrites upon repeated charge-discharge cycles. While those drawbacks have not stopped research on metallic-lithium batteries, it has certainly stimulated interest in batteries based on lithium compounds, but which do not contain the metal itself. One of the most promising of these is the lithium-ion battery.

In the rocking chair

In a lithium-ion cell, the plates are both made of intercalation materials—materials having a lattice structure into which a guest species (lithium ions in this case) may be inserted and extracted with not too much structural modification of the host. More specifically, a fully charged negative plate is made of lithiated carbon, which is about 15 percent lithium by weight and has almost the same electrochemical potential as metallic lithium. The electrode may be based on graphite or petroleum coke. Graphite results in a higher-capacity battery with a flatter discharge characteristic, but petroleum coke is less incompatible with most of the suitable electrolytes.

The discharged positive plate employs one of three intercalation compounds—$LiCoO_2$, $LiNiO_2$, or $LiMn_2O_4$—each of which develops a substantial voltage of 3.5–3.8 V with respect to lithium (or a little less versus lithiated carbon).

In operation, lithium ions move back and forth between the two plates as the cell is alternately charged and discharged—hence the nickname "rocking-chair technology," or RCT.

RCT's great gift to battery designers is that no metallic lithium is plated during the charge, and, to repeat, no lithium metal is present in the cell at all. Some regulatory agencies do not consider RCT batteries to be "lithium" batteries for shipping purposes.

The theory behind RCT is far from simple and the details of constructing one can get quite complex as well. There are technical problems to be overcome and tradeoffs to be negotiated for both electrodes and the electrolyte, *Spectrum* was told by Sohrab Hossain, program manager of the secondary lithium battery program at Yardney Technical Products Inc., Pawcatuck, Conn.

To begin with, a lithiated-carbon negative electrode is sensitive to air. In moist air, it undergoes a reaction that, in effect, converts it back into ordinary unlithiated carbon. Therefore, in manufacturing lithium-ion cells, the negative plate is made of unlithiated carbon, and is lithiated (by being charged) only after the cell is sealed.

During this formation cycle, some lithium is permanently transferred from the positive plate to the negative one. Since the cycle is critical in determining the cell's storage capacity, lithiation is carried out in the factory, and lithium-ion cells are shipped wholly or partially charged.

As with the negative plate, the best materials for the positive electrode are intercalation compounds in which there is little bonding or structural modification of the host material during the charge or discharge reaction. Of the three materials cited above, $LiCoO_2$ and $LiNiO_2$ yield slightly higher capacity than $LiMn_2O_4$, but the last-named is produced from less toxic and less expensive materials and is therefore likely to become the material of choice as the technology matures.

Unlike conventional lead-acid or alkaline batteries, RCT cells are based on nonaqueous electrolytes, usually a salt dissolved in an organic solvent. The main issues in selecting an electrolyte are compatibility with the chosen electrode materials, good ionic conductivity, and thermal stability up to 90 °C. If the negative electrode consists of lithiated graphite, then the choice of electrolyte is pretty much restricted to systems based on ethylene carbonate since those based on other solvents tend to cause exfoliation of the graphite.

If lithiated coke is used for the negative plate, then a much wider choice opens up: diethylene carbonate, propylene carbonate, dimethyl carbonate, and many other solvents that may be used singly or in combination. The favorite solute is lithium hexafluorophosphate ($LiPF_6$) but other lithium salts may be used. The ionic conductivity of the mixtures is some two orders of magnitude lower than that of aqueous alkaline electrolytes, and is high enough to make practical batteries for use at or above room temperature, provided the electrodes have large surface areas and are very closely spaced.

Actually, even at 0 °C the ionic conductivity of these electrolytes (above 1 mS/cm) suffices for practical batteries. It does, however, vary quite a bit with temperature. It ranges from 0.23 mS/cm at –40 °C up to 14.63 mS/cm at +40 °C for a fairly typical system ($LiPF_6$ dissolved in a 50/50 volume mixture of ethylene carbonate and propylene carbonate). Clearly, then, if RCT batteries are to power electric vehicles, they will have to be heated in winter.

Speaking of electric vehicles brings to mind the subject of fast charging, which some people believe is essential for a successful EV battery, and which many people also desire in batteries for portable equipment. Lithium-ion batteries look pretty good when it comes to fast charging since they can be fully charged in less than two hours following a modified constant-current regime. More specifically, for a cell with a $LiCoO_2$ cathode, the battery may be charged at its 1.5C-rate (a current in amperes numerically equal to 1.5 times the battery's capacity in ampere-hours) until the voltage reaches 4.2 V, which takes about an hour. Then the voltage is kept steady at that level until the current tapers off to a very low level (close to zero milliamperes) in about an hour more. People in a hurry may terminate the charging when 4.2 V is reached; at that point the battery will be about 90 percent charged.

The nub of the charging process is the absolute necessity of setting strict limits on the charging voltage on each cell. Failure to do that may cause the cathode and electrolyte to decompose, the pressure in the cell to rise, and metallic lithium to plate onto the carbon surface of the negative electrode. The need for careful charge control on each individual cell has serious implications for batteries made up of many cells—electric-vehicle batteries, for example.

Solid progress

Impressive as it is, the lithium-ion cell is not the metal's ultimate battery technology, as far as capacity is concerned. Cells with negative electrodes composed of metallic lithium can, in theory, store about 10 times more energy per unit weight than those with negative plates of lithiated carbon. In practice, however, the metal's high reactivity militates against achieving more than about a 2:1 advantage.

The trouble is that the lithium electrode has a tendency to react with any liquid electrolyte, creating a sort of passivation film. The reaction would have little effect on the specific energy if it happened only once; but every time the lithium is stripped away and then replated as the cell is discharged and then recharged, a fresh metal surface is exposed to the electrolyte and a new film is formed. The process uses up a lot of lithium. To compensate, cells with metallic lithium electrodes and liquid electrolytes are loaded up with an excess of the metal, which costs them much of their theoretical weight advantage.

Exacerbating the situation are the structural changes that occur in the lithium electrode during charging, when the metal is replated. The plated metal is more porous than the original, and the porosity adds to the metal's surface area and, hence, to its inclination to react with the electrolyte.

Partially because of these difficulties, many organizations are pursuing research

into lithium batteries with solid polymer electrolytes, with which the metal reacts less than it does with liquids. In a lithium-polymer cell, a film of metallic lithium would be bonded to a thin layer of a solid polymer electrolyte, which would be backed by a layer of one of many possible positive-electrode materials and then by a highly conducting current collector [see cross-sectional drawing on p. 53]. Note that the solid polymer enhances the cell's specific energy by acting as both electrolyte and separator.

A layered structure of this type, if perfected, would have many attractions. It could be fabricated in a continuous process by web equipment something like a miniaturized newspaper press, but running in a vacuum or an inert atmosphere. Batteries of such cells could be made in almost any desired shape and size, their lack of liquid would make them fairly safe, they would have the highest specific energy rating of any known battery, and they would hold their charge for years with very little loss.

The trouble here is that, at room temperature, suitable solid polymer electrolytes have a rather low ionic conductivity, on the order of 0.01–1 μS/cm. In order to improve those numbers, researchers are experimenting with a variety of salts, organic solvents, and other dopants.

They have had some degree of success. On the one hand, they have produced solid polymer electrolytes with conductivities on the order of 10–100 μS. But on the other hand, the plasticized and gelled electrolytes are less stable than the simpler ones because they are more reactive with lithium.

In point of fact, even the heavily doped solid polymer electrolytes are one or two orders of magnitude less conductive than most organic liquid electrolytes, so they are always made quite thin. But at 50 μm thick or less, they become vulnerable to such mechanical risks as tearing and pinhole defects.

The growth of dendrites on the lithium electrode is also a problem since they can puncture the polymer film and short-circuit the cell. When plated onto the lithium film during charging, the metal is usually deposited fastest in regions where the electric field is strongest—namely, where there are slight mechanical discontinuities in the existing metal. As the dendrite builds, the geometry favors its growth ever more strongly, since the discontinuities worsen and so boost the local peak in field strength.

The problem is attacked by a new process for producing Li-polymer cells. Usually, lithium is rolled into a foil, which is then pressed into the surface of a polymer film. The alternative approach, developed at Battelle Pacific Northwest Laboratory, Richland, Wash., is to vacuum-deposit an ultrasmooth polymer film and then to deposit the lithium electrode on it by electron beam evaporation without ever breaking vacuum and exposing the surface to air or handling. According to John Affinito, staff scientist at Battelle, the polymer multilayer (PML) process yields polymer layers smooth enough for optical interference coatings. Thus, depositing the lithium over this smooth surface greatly reduces dendrite formation.

The zinc-air cell

The very latest type of rechargeable battery to move from the research laboratory to the marketplace is based on zinc-air technology. (Zinc-air primary cells have of course been around for years.)

Primary and secondary zinc-air cells look alike. Both have a zinc negative electrode, a potassium hydroxide electrolyte, and a carbon positive electrode, which is exposed to the air. During discharge, in both types of batteries, oxygen from the air is reduced at the carbon electrode—the so-called air cathode—and the zinc electrode is oxidized.

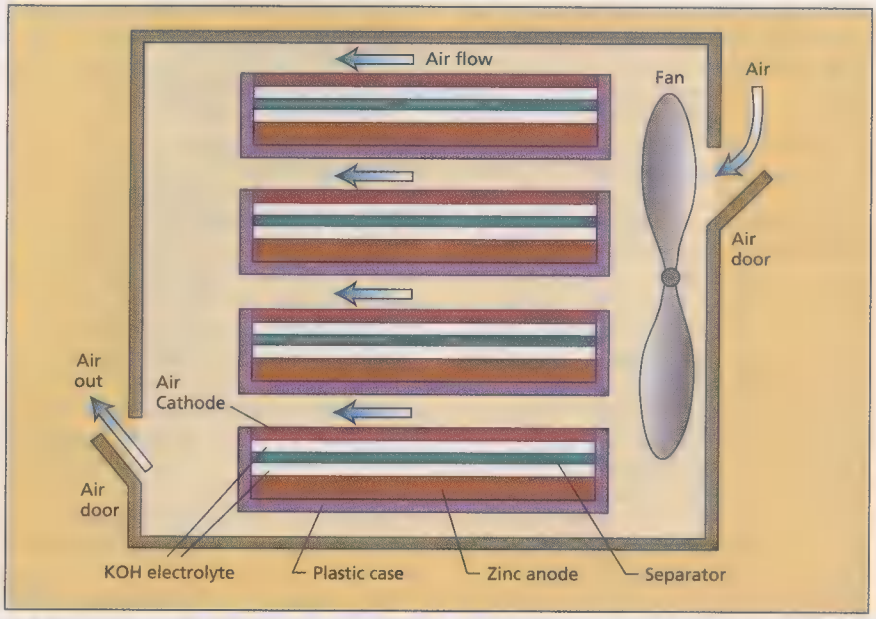
The difference is that the oxygen electrode in the rechargeable cell allows that reaction to be reversed. Not only can it absorb oxygen from the air and convert it into oxygen ions for transport through the electrolyte to the zinc anode during discharge, but it can evolve oxygen while the battery is being charged.

A big weakness of early zinc-air batteries was their very low specific-power ratings—on the order of 10 W/kg. The oxygen electrode was the problem. It simply could not absorb oxygen fast enough to support reasonable discharge rates, nor could it evolve oxygen fast enough to support reasonable charge rates.

The solution involved impregnating the oxygen electrode with catalysts and rendering it sufficiently porous to give it a very large surface area (without letting the electrolyte leak through). The pioneers in the field were Westinghouse Electric Corp., based in Pittsburgh, and Dreisbach Electromotive Inc. (DEMI), Santa Barbara, Calif. The companies each hold patents and have licensed their technology to AER Energy Resources Inc., Smyrna, Ga., for use in producing rechargeable zinc-air batteries for portable products. Also, DEMI has spun off another company, Zinc Air Power Corp., Canton, Mich., to develop large zinc-air batteries for electric vehicles.

But a good air cathode alone does not a zinc-air battery make. An air-management system is also a necessity, as is a means for coping with the increase in volume that occurs when the zinc is oxidized. The air-management system ensures that the flow of air into the battery generates the required power, without excessively drying the oxygen electrode. It also restricts or completely blocks the air flow when little or no energy is being drawn, vastly reducing the battery's self-discharge.

In the large batteries under development by Zinc Air Power and the smaller ones being sold by AER Energy, a combination of an air door and a fan manages air flow [see drawing below]. With the door



Air management is critical to the successful operation of a zinc-air battery. When no current is being drawn, the air doors seal the battery from the ambient air and consequently greatly reduce the self-discharge rate.

A comparison of the most promising batteries

Cell type	Nominal voltage, V	Specific energy, Wh/kg	Energy density, Wh/L	Specific power, W/kg	Power density, W/L	Self-discharge, %/month	Cycle life[a]	Comments
Alkaline[b]	1.5	150	375	14	35	0.3	1	Not rechargeable
Lead-acid	2.0	35	70	~200	~400	4–8	250–500	Least-cost technology
Lithium-ion	3.6[c]	115	260	200–250	400–500	5–10	500–1000	Intrinsically safe; contains no metallic lithium
Lithium-polymer[d]	3.0	100–200	150–350	>200[e]	>350[e]	~1	200–1000	Not yet available commercially; contains metallic lithium
Nickel-cadmium	1.2	40–60	60–100	140–220	220–360	10–20	300–700	Exhibits memory effect
Nickel-metal hydride[f]	1.2	60	220	130	475	30	300–600	May exhibit slight memory effect—experts disagree
Zinc-air[g]	1.2	146	204	150	190	~5	~200	Requires air manager to limit self-discharge

[a] Very broad ranges are shown because cycle life is strongly dependent on how the battery is treated.

[b] Data on the popular Duracell alkaline D cell is included just to put rechargeable batteries in perspective.

[c] Li-ion cells with petroleum coke anodes drop from about 4.0 to about 3.0 V, in fairly linear fashion as they go from fully charged to fully discharged.

[d] Since commercial units are at least a year away, these figures are only predictive.

[e] These power figures apply at full charge; they will drop considerably ■ the cell discharges.

[f] Ni-MH data applies to 2.9-Ah 4/3 A cells, of the kind made by Duracell and Toshiba.

[g] Zinc-air data is for the cell that Zinc-Air Power is about to use in ■ prototype battery for electric vehicles.

▲ For all their seeming hardness, these figures give at best a rough notion of how the technologies compare. Truly comparable cells are not made in every technology. The data was not obtained under identical conditions from all cell types. Note also that data on specific energy and specific power may not always apply to the ■■■ device, since cell designs may maximize one at the expense of the other.

open and with the fan running, the batteries can deliver full power. For a small battery, shutting down the fan and leaving the door open cuts down on self-discharge, while still allowing the battery to put out sufficient power to run a computer in its sleep mode. And, of course, closing the door also effectively shuts down both types of battery. Zinc-air batteries with air management have some of the lowest self-discharge rates—something like 5 percent per month.

The presence of the air-management system means that even small zinc-air batteries are not really small. They are certainly not supplied as AA cells, but are manufactured and sold as modules weighing perhaps 3 kg and occupying a volume of some 3000–4000 cm^3.

However, the air-management system does not absorb a lot of a battery's energy. The amount of air required by a zinc-air cell is quite low. According to the *Handbook of Batteries*, the quantity required to produce 1 A of continuous current is a mere 18.1 cm^3/min, or about a liter an hour. A rather small fan will serve even an electric vehicle battery capable of delivering hundreds of amperes.

Naturally, the small zinc-air batteries intended for portable computers and those used in electric vehicle applications have their differences. The vehicle batteries incorporate filters for removing carbon dioxide from the incoming air and include a small pump for recirculating the electrolyte. Removing the carbon dioxide from the incoming air is desirable because the gas tends to react with the KOH electrolyte so as to form potassium carbonate, which eventually plugs up the oxygen electrode. For small battery modules, the added size and weight are simply unacceptable, so the filter is omitted and the cycle life of the battery is reduced. For large batteries, the penalty is negligible and the added life is well worth it.

One weak point of zinc-air batteries is sensitivity to electrical abuse. They cannot be quick-charged, and if they are discharged below about 0.9 V (nominal operating voltage is 1.0–1.2 V), they may be permanently damaged.

To counter these shortcomings, zinc-air batteries have built-in monitoring and charging circuitry. The first type monitors the voltage of each cell, puts out an alert signal as cutoff approaches, and shuts the battery down when cutoff is reached. The second charges the cells under a constant-voltage regime, at ■ voltage of around 2 V, with current limiting. Charging ends when the current tapers off to ■ specified value. ●

To probe further

An extremely comprehensive source of information on batteries of all types is *Handbook of Batteries* (McGraw-Hill, New York, 1995), now in its second edition. Its editor in chief is David Linden.

Another good general reference is the section on batteries in the *Kirk-Othmer Encyclopedia of Chemical Technology*, Vol. 3, fourth edition (John Wiley & Sons, New York, 1992).

For a more focused look at the best developed of the secondary battery technologies—lead-acid, nickel-cadmium, and nickel-metal hydride—get hold of *Maintenance-Free Batteries* by D. Berndt (published by Research Studies Press, Taunton, Somerset, England, 1993, and distributed by John Wiley & Sons, New York).

For an up-to-date survey of the state of the art in small batteries, both primary and secondary, see "Batteries for Low Power Electronics" by Robert A. Powers, *Proceedings of the IEEE*, Vol. 83, no. 4, April 1995, pp. 687–693.

Sleuthing out GRAVITATIONAL WAVES

Because gravity is 40 orders of magnitude weaker than the Coulomb force, the detection of gravitational waves is a huge challenge to instrument builders

ONCE UPON A TIME, in the Large Magellanic Cloud—one of our Milky Way's two companion galaxies—a star exploded, nearly destroying itself. One hundred sixty thousand years later, in 1987, radiation from that event finally reached earth. The first to see the brightening star were astronomers in the southern hemisphere. (The last supernova visible to the naked eye had been Kepler's discovery in 1604.)

Scarcely 24 hours earlier, in other parts of the world, other types of detectors had bestirred themselves. In Italy, at the University of Rome, and in the United States, at the University of Maryland at College Park, gravitational-wave detectors registered 12 fairly large and about 100 small pulses over a period of two hours. Around the same time, the Mont Blanc Neutrino Observatory in France registered five pulses of neutrinos over a 7-second interval. Similar recordings were made by neutrino detectors in Kamioka, Japan, and Fréjus, France.

Astrophysicists are still debating the significance of the observations of those two days, Feb. 23 and 24. But others claim the pulses registered in Rome and Maryland may have been due to actual gravitational radiation from an identifiable source—the supernova of 1987.

Physicists find this ambiguity unsatisfactory. They want to detect the gravitational waves themselves, directly and unequivocally. Indeed, the waves' detection has been called "the most important of all tests" of Einstein's general theory of relativity by theoretician Kip S. Thorne of the California Institute of Technology (CalTech) in Pasadena. The sensing or reception of gravitational waves may also deepen astronomers' understanding of the dynamics of violent events such as supernovae, exploding black holes, and the interactions between black holes and neutron stars. As a bonus, whatever is learned about detecting ultra-weak signals might help engineers measuring extraordinarily small displacements or strains.

The big deal

According to Einstein's general theory of relativity, all objects exist in four-dimensional space-time (that is, in a continuum having three dimensions of space and one of time). Every object's mass curves space-time, a curvature that manifests itself as the mass's gravitational field. The greater the mass, the greater the curvature of space-time, and the greater the gravitational field.

Also according to Einstein's theory, massive objects that rotate or explode asymmetrically, or oscillate, give off gravitational waves or ripples that propagate through space-time, like ripples or waves on the surface of the ocean [see "Defining the target," p.60].

Gravitational waves conform to an inverse square law relationship, just like electromagnetic waves. The force of both types of energy declines in proportion to the square of their distance from their source. But gravitational waves are fully 40 orders of magnitude weaker than the Coulomb electric force. In other words, the ratio of electromagnetic to gravitational forces between an electron and a proton is approximately 10^{40}. Thus, the detection of such vastly weaker waves is a monumental challenge to instrumentation.

The evidence that gravitational waves exist is compelling, albeit indirect. The firmest relies on observations made over seven years by astronomers Joseph Taylor, of Princeton University in New Jersey, and Russell Hulse, then at the University of Massachusetts at Amherst but now also at Princeton. Their measurements of radio waves from a binary pulsar designated PSR1913+16 show that the pulsar's 8-hour orbit around the neutron star is gradually contracting; the faster the pulsar revolves around the neutron star, the smaller its orbit gets. As the rate of decrease agrees to within 0.5 percent with predictions derived from the general theory of relativity, the finding is excellent circumstantial evidence for orbital decay being a result of energy lost by gravitational radiation [see graph, p.58]. Even though the gravitational radiation itself was not detected, Taylor and Hulse shared the 1993 Nobel Prize in Physics for this work.

But what would it take to observe the weak gravitational radiation directly?

Gravitational waves are generally believed to travel at the speed of light and to deform or distort an object geometrically as they pass through it. For plane-

MELVIN A. LEWIS
Loral Electronic Systems Inc.

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polarized gravitational waves, the two directions are at 45 degrees to each other, not perpendicular as they are for light. In other words, a passing gravitational wave distorts an object first in one direction, then (in the next half-cycle) in another, rotated at a 45-degree angle to the initial direction. It takes another half gravitational-wave cycle for the wave to distort at the 90-degree angle characteristic of electromagnetic waves in the first half-cycle.

In principle, this distortion and its aftereffects should be possible to sense with the aid of strain detectors attached to a suitable "antenna"—a space-time seismometer, if you will. But such an antenna resembles nothing familiar to electrical engineers. In its simplest manifestation, the antenna is a large solid cylindrical bar [see top figure, opposite].

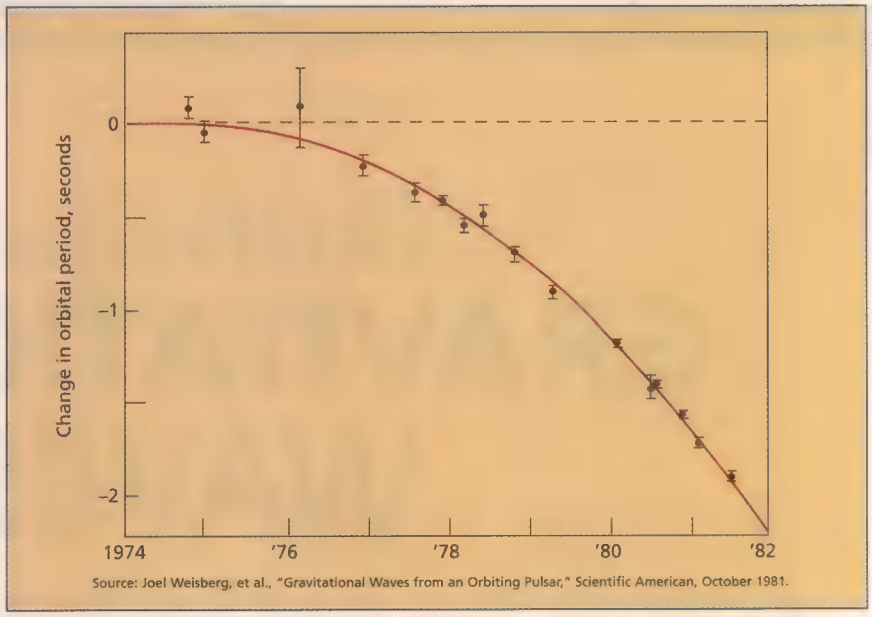
The pioneering resonant-bar detector was designed in the late 1950s and built in the early '60s by Joseph Weber, professor of physics at the University of Maryland. Weber's design called for a mechanically isolated cylinder of solid aluminum weighing several metric tons. Piezoelectric strain transducers attached at intervals around its circumference converted the vibrations induced by any passing gravitational wave into an electric signal. Weber's bar resonated mechanically around 1 kHz, so that it would "ring" after being distorted by an incoming damped-exponential wave—the shape expected of a gravitational wave from a supernova. Subsequently, other bar detectors were built at many institutions around the world.

The main problem with resonant-bar antennas is their insensitivity. Even the latest of them yield dimensionless strain sensitivities of about one part in 10^{18} (that is, only 10^{-18} meter distortion per meter of length), too little to detect gravitational waves from any but the nearest and most violent events.

The laser alternative

The laser interferometer owes its sensitivity in detecting gravitational waves to an arrangement of mirrors suspended on vibration-isolated pendulums. Two pairs of mirrors create two light paths perpendicular to one another. A laser beam is split and the halves sent down each path, rebounding back and forth along the leg between the mirrors hundreds of times before being recombined. The multiple passes create the very long light path required to amplify the gravitational-wave input to detectable amplitude [see bottom diagram, opposite].

In brief, if a gravitational wave passes by, the pendulums holding the mirrors are expected to move a little apart in one leg and a little together in the other leg, in each case by the same tiny fraction of the laser light wavelength. Their movement shifts the relative phase of the two halves of the laser beam, momentarily upsetting the interference patterns that would otherwise cancel out. At that instant, the interference pattern brightens by an amount proportional to the strength of the gravitational wave. The job of monitoring the interference pattern for brightening is handled by electro-optic detectors, which indicate when a passing gravitational wave is detected and which recover its variation over time.



ILLUSTRATIONS: MORRIS KHAN

▲ As the binary pulsar PSR1913+16 emits gravitational waves, it loses energy and its orbital period decreases. The agreement of the decrease to within 0.5 percent of predictions from the general theory of relativity represents the first indirect detection of gravitational waves. The pulsar was discovered in 1974 by Princeton University astronomers Joseph Taylor and Russell Hulse (the latter then at the University of Massachusetts at Amherst), who shared the 1993 Nobel Prize in Physics for their work.

Weber soon realized that a laser interferometer was potentially a more sensitive means of detecting gravitational waves. About that time, the early '60s, the same idea occurred independently to Mikhail Gerstenshtein and V. I. Pustovoit at Moscow State University in the then USSR and to Ranier Weiss at the Massachusetts Institute of Technology in Cambridge.

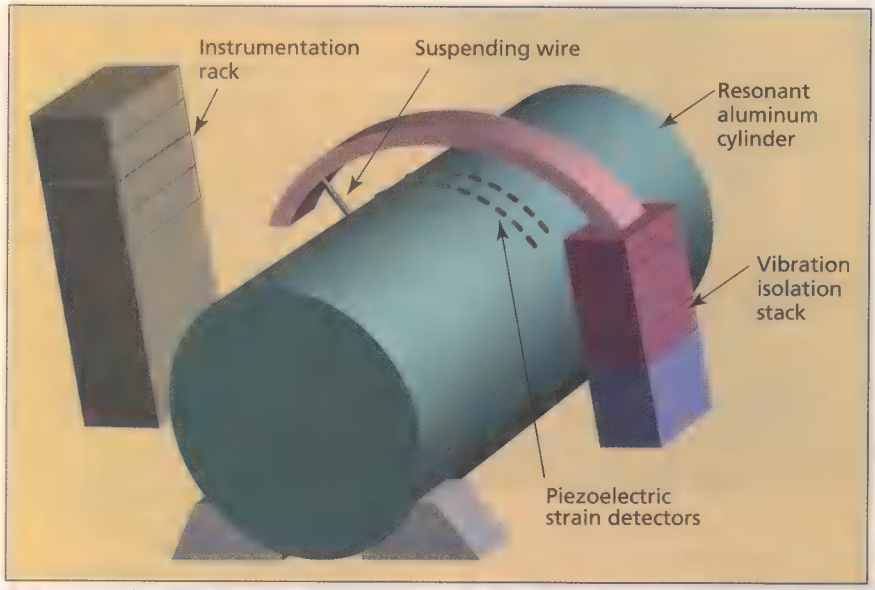
But it was 1978 before the first gravitational-wave detector to be based on a laser interferometer was actually built, by Robert L. Forward, then at Hughes Research Laboratories, Malibu, Calif. Its legs (the distance between mirrors) were 2 meters long. Five years later, in 1983, a prototype with 40-meter-long legs was installed at CalTech. Designed by physicists at MIT as well as CalTech, it could measure movements of one part in 10^{14}. The figure was subsequently improved to one part in 10^{18}—on a par with most resonant-bar detectors. Similar prototype setups now exist in Italy, Germany, Japan, and elsewhere. But laser interferometers can be made far more sensitive.

The success of the CalTech prototype has led to the funding of twin large-scale laser-interferometer detectors, which together make up the Laser Interferometer Gravitational-wave Observatory (LIGO). Within four years, these two instruments should be at least three orders of magnitude more sensitive than any other laser interferometer detector built to date.

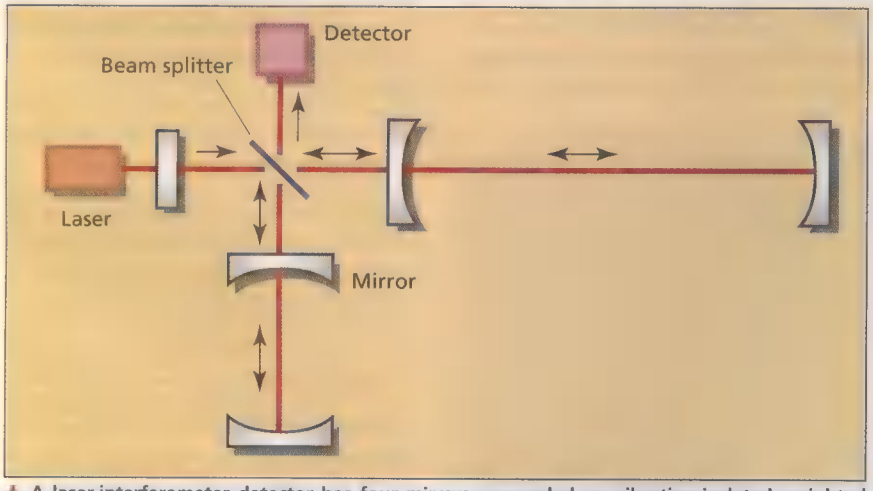
For both LIGO interferometers, the distance between the mirrors of each leg is to be all of 4000 meters, down which will travel split beams from an argon laser at a green wavelength of 500 mm [see figure on p.61]. The beams will travel inside evacuated pipes 1.22 meters in diameters, to eliminate brightness fluctuations when a laser beam collides with air molecules. To minimize false positive detections due to phase artifacts, the laser's frequency (wavelength) will have to be stabilized to an unprecedented degree—much better than 1 μHz per square root of the laser's frequency in hertz.

One of LIGO's interferometers is being built in Hanford, Wash., and the other in Livingston, La. Construction has begun at Hanford, where the site should be ready for the installation of the interferometer in 1998, and operation is to begin by 2000. Each will provide a cross-check on the other, ensuring that pulses due to laser fluctuations, seismic vibrations, and other disturbances at one facility can be detected as false positives after comparison with signals or noise measured at the other facility.

At first, the LIGO should yield a sensitiv-



A resonant-bar detector is a mechanically isolated solid cylinder that resonates mechanically at the frequency expected of an incoming gravitational wave. Strain transducers around the unit's circumference convert the vibrations induced by a gravitational wave into an electrical signal.



A laser-interferometer detector has four mirrors suspended on vibration-isolated weighted pendulums to create two mutually perpendicular light paths. A laser beam is split and sent down each leg, bouncing off the mirrors many times before being recombined to create a very long lightpath. If a gravitational wave passes by, the pendulums holding the mirrors are expected to move—apart in one leg and together in the other—by a tiny fraction of the laser light wavelength. The movement would shift the relative phase of the two halves of the split laser beam, upsetting the mutual cancelation of the interference patterns at the detector and registering as a detection of a gravitational wave.

ity of a few parts in 10^{21}. Eventually, it should attain nearly one part in 10^{23}, the ultimate limit on sensitivity, as determined by the quantum uncertainty of the position of the mirrors.

Not only are laser-interferometer detectors potentially more sensitive than resonant-bar antennas—they are also better at detecting a variety of sources because they are inherently broadband. They respond to gravitational waves having a frequency from 10 Hz to 10 kHz, versus the resonant-bar antennas' 1-Hz bandwidth at 1 kHz. Admittedly, the resonant-bar antenna's narrow bandwidth makes it easier to filter noise out. But even that is a mixed blessing: unless the wave is periodic, narrow filtering causes the receiver to discard most of the wave's detail.

Input from space

A third and truly exotic method of detecting gravitational waves has also been proposed: monitoring the Doppler shift of the carrier frequency (or rather, the retransmission of the tracking station's frequency) from two or more interplanetary spacecraft simultaneously.

The technique is analogous to laser interferometry. The idea is to detect the Doppler shift in a spacecraft's microwave frequency as the craft is jostled by a passing gravitational wave—that is, as spacetime is warped in its vicinity. The spacecrafts' tremendous distance from the earth and from one another amplifies the frequency shift that might occur when a gravitational wave traverses the line between the earth and each spacecraft. The Doppler method should be able to detect ultralow-frequency gravitational waves in the 0.01–0.0001-Hz range.

Some work was started by, among others, Ronald Hellings at NASA's Jet Propulsion Laboratory, Pasadena, Calif. Signals from three interplanetary probes (Galileo, Ulysses, and the Mars Observer, then en route to Mars) were monitored for frequency shifts due to gravitational waves; but no results have yet been published from this 1993 experiment, led by John Armstrong, also at the Jet Propulsion Lab.

Inevitably, there are obstacles to overcome. Since the effects of a passing gravitational wave are so small, the reference oscillator must be extremely stable to detect any Doppler shift. Observers must also take into account variations in the pressure of the solar wind (which differs from time to time and with the changing distance of the spacecraft from the earth), in forces from the attitude control thrusters (used to occasionally correct the spacecraft's orientation), and in the refraction of the earth's atmosphere (through which the signal must travel). Subtracting all these variations, the interplanetary detector is expected to have a theoretical sensitivity of about one part in 10^{16}—corresponding to a displacement of about 0.065 mm over the shortest distance from the earth to Jupiter and an eighth of that over the shortest distance from the earth to Mars.

Less noise, please

Noise degrades the sensitivity of any gravitational-wave receiver. The interference is mostly due to seismic activity in the earth, acoustic interference (also known as microphonics) from inhabited surroundings, and heat (thermal noise). Especially troublesome are the non-Gaussian tails of noise distribution, which produce a significant number of false detections.

The laser interferometer suffers in addition from photon shot noise, which is due to quantum fluctuations in the number of detected photons. Photon shot noise limits the accuracy of measurement of the optical phase difference above 100 Hz, while acoustic and seismic vibrations limit sensitivity below 100 Hz. In addition, the pendulums holding the end mirrors must not rotate and the laser beam must be steady in amplitude and direction as well as highly monochromatic.

Today's resonant-bar detectors are isolated from vibration and acoustic noise in several ways. Some detectors use unusual



UNIVERSITY OF WESTERN AUSTRALIA

A cryogenically cooled resonant-bar gravitational-wave antenna was built at the University of Western Australia, Nedlands, in the mid-1980s. The cylinder of solid niobium, pulled out from the enclosure, is suspended from a room-temperature stack that isolates it from vibration and is contained within multiple dewar housings for cryogenic cooling.

spring arrangements while others employ active electromechanical cancelation and/or cascaded stacks of layers of steel or lead plates alternating with rubber pads. These methods provide attenuation up to 250 dB. Acoustic isolation is further improved by enclosing the detector assembly inside an evacuated chamber with thick walls.

Thermal noise is handled another way. The anticipated distortion or strain of a resonant bar from a gravitational wave is five orders of magnitude smaller than the diameter of one atomic nucleus. In that context, the noise produced by the random thermal agitation (Brownian motion) of the bar's molecules is overwhelming. What makes it possible, even so, to detect such minute strains is that they are coherent, whereas the Brownian motion is random. Moreover, the Brownian motion can be reduced by cooling the detector with liquid helium to a temperature of 4.2 K. Some setups are further cooled to 0.05 K by an active process known as dilution refrigeration.

In either case, superconducting amplifiers may then be used with little increase in the complexity of the mechanical design. Some researchers, for example, are using superconducting quantum interference devices (Squids), a component that is extremely sensitive to changes in magnetic flux. Already in use in medical electronics, Squids generally serve as the first-stage post-detection amplifier because they are over 1000 times as sensitive as room-temperature FET amplifiers.

When a gravitational wave passes through the cylinder and distorts its shape, the moving input coil produces minute changes in the magnetic flux. That magnetic flux change then creates a relatively large variation in the voltage across the Squid junctions. In turn, these variations are passed along as voltage signals to succeeding stages of amplification—generally room-temperature FET amplifiers with optimal filtering for the anticipated signals. If tuned mechanical transformers or resonators are installed between the antenna and the transducer, transfer of the gravitational wave's pulse is maximized and amplifier noise coupling is minimized.

Refining sensitivity

To prolong the resonant ringing of the antenna itself, it is necessary to maximize the antenna's Q (a figure of merit equal to the antenna's resonant frequency divided by bandwidth). Higher Qs give a longer sustained response to the incoming wave, so that the noise from Brownian motion can be more effectively averaged out. In addition, along with higher Qs comes lower noise power plus the concentration of that noise power into a narrower bandwidth, facilitating filtering.

Aluminum alloyed with magnesium has a Q greater than 10^7 at 4.2 K. Even higher Qs can be obtained by employing exotic single-crystal materials. At cryogenic temperatures, Qs as great as 10^{10} can be achieved from a mass of single-crystal sapphire. Clearly, that approach is expensive; as a compromise, polycrystalline niobium is capable of a Q of 10^8 and is available in masses of a thousand kilograms at moderate expense.

With single-crystal materials, however, the oscillations in the resonant-bar antenna should last many hours. Integration of the oscillations would reduce the noise (which is random) and increase the signal (which is coherent). The approach enhances the net sensitivity—though at the price of losing the signal's temporal characteristics (wave shape).

Moreover, for sensitivity greater than one part in 10^{21}, the measurement strategy must change in order to push the quantum limit of the noise. Some teams—one of the first being that headed by Vladimir Braginsky at Moscow State University—have taken an exotic approach known as quantum nondemolition detection or back-action evasion detection.

Defining the target

Gravitational waves are generated only by the equivalent of a rotating or oscillating system—that is, two or more masses accelerating toward or away from each other and exhibiting what is called a quadrupole moment of inertia.

Only such quadrupole and higher multipole sources can generate gravitational waves because, whereas there are negative electric charges, there are no negative masses. A negative electric charge oscillating back and forth is the equivalent of a positive charge moving in the opposite direction, and this equivalence enhances the generation of electromagnetic waves. Since there is just one gravitational polarity, however, a mass can oscillate only with respect to a counterweight. This counterweight reacts to the oscillation and generates a gravitational disturbance that almost, but not quite, cancels the disturbance of the first body.

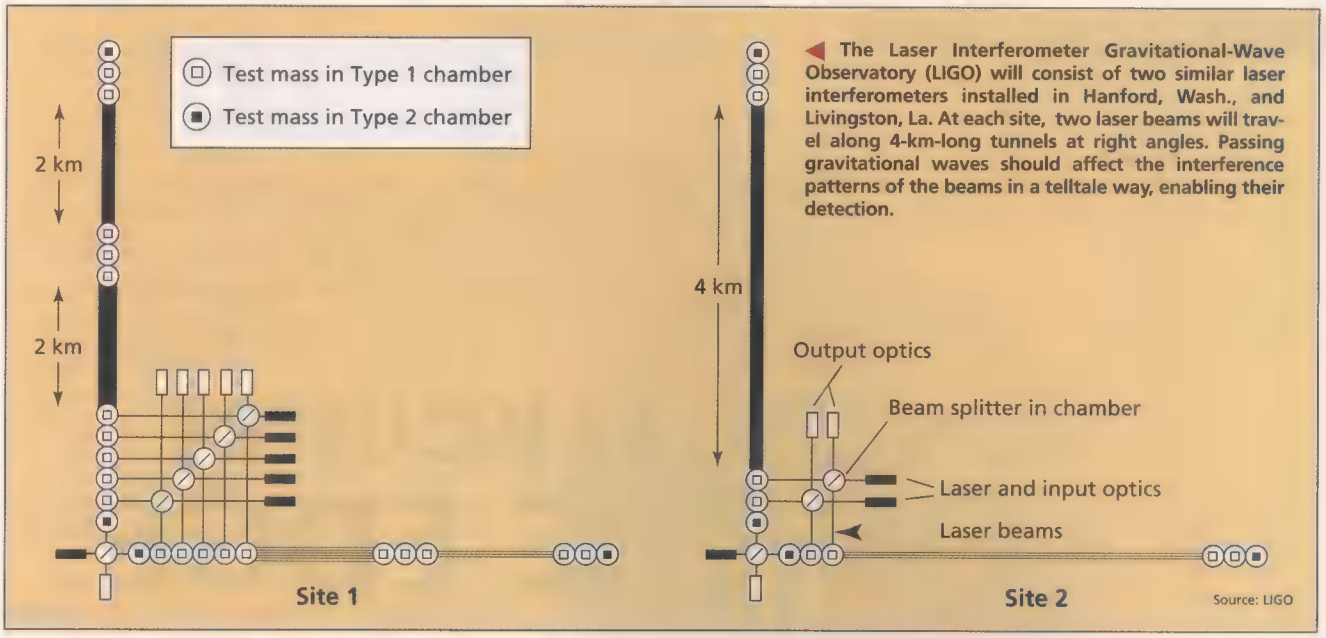
As explained by physicist Paul Davies of Australia's University of Adelaide, the gravitational disturbances would completely cancel out but for the time required for them to travel between the masses. It is this out-of-phase imbalance in the cancelation of the disturbances that propagates as a gravitational wave. For this reason, such waves are not generated by quiescent stars, those rotating on their axis symmetrically or even exploding symmetrically, because there is no quadrupole moment (although that situation changes if they explode asymmetrically or change their shape).

A typical binary star system, however, does have a quadrupole moment and should produce a slow periodic gravitational wave. A binary star system near enough would cause a measurable distortion a little in excess of one part in 10^{21} on earth.

For the wave to lie in the frequency range (typically 1000 ± 1 Hz) of the gravitational-wave detector, though, the two stars of the binary must be in the final stage of coalescing, a rare situation. For comparison, a supernova is expected to produce damped exponential impulse waveforms each lasting 1 millisecond. A collision or collapse of a binary system between two neutron stars or between a neutron star and a black hole would produce gravitational waves with a sliding frequency in the 1–1000-Hz range as one star spirals in on its partner.

Physicists also believe that the universe itself might be a source of gravitational radiation in the form of continuous noise, originating during the Big Bang explosion at its birth.

—M.A.L.



◀ The Laser Interferometer Gravitational-Wave Observatory (LIGO) will consist of two similar laser interferometers installed in Hanford, Wash., and Livingston, La. At each site, two laser beams will travel along 4-km-long tunnels at right angles. Passing gravitational waves should affect the interference patterns of the beams in a telltale way, enabling their detection.

The Heisenberg uncertainty principle states that the measurement of an object's position will disturb the measurement of its momentum, and hence its velocity (that is, will introduce noise), so that beyond a certain limit both position and momentum cannot be measured simultaneously.

The effect of the uncertainty principle's noise fluctuations can, however, be modified. The means is parametric pumping, with a nonlinear optical medium covering the open beam-splitter port. The pumping increases the fluctuations in one quadrature phase of the interferometer's output light, while decreasing those in the orthogonal (90-degree) quadrature phase. In effect, the fluctuations become "squeezed" out of one quadrature phase into the other, making the signal clearer. While the principle of quantum nondemolition has been shown to work, a detector with a sensitivity below the quantum limit has yet to be built.

The scale of the antenna's 'area'

The sensitivity of any gravitational-wave receiver is also limited by the antenna's effective gravitational cross section, a quantity analogous to an RF antenna's effective area. In the resonant-bar detectors, the effective gravitational cross section is determined by the antenna's length and mass. In essence, the bar is viewed as a single-mass quadrupole, vibrating as a classical harmonic oscillator that is driven by the space-time curvature (the Riemann tensor); then solving for the vibration determines the net absorption and hence the cross section. Mathematical estimates put the gravitational cross section of a multi-ton aluminum cylinder at only about 10^{-24} m^2, or much smaller than a helium atom!

Such dimensionality should be no deterrent. After all, though a resonant bar's cross section to gravitational waves may be minuscule, the cross section of neutrino interaction with matter is also almost vanishingly small—but neutrino astronomy is an active, successful endeavor, with many detections confirmed to date. Further, improvements in the bar detectors and interferometers now on the drawing boards are expected to enable them to detect gravitational waves from collisions of black holes throughout most of the universe, resulting in many events per year.

So were gravitational waves recorded from the 1987 supernova, as Weber believes? Not everyone agrees. In the light of his statistical analysis of the data, Bernard F. Schutz, at the University of Wales at Cardiff, claims the pulses reported from several gravitational-wave detectors are not convincing enough evidence. CalTech's Thorne holds the same position.

So for the time being, the "did we or didn't we see anything" controversy continues in the gravitational-wave community. To decide the issue, what is needed is is more sensitive instrumentation plus consistent, verifiable detections. LIGO and the instruments now coming on line may allow physicists at last to detect unambiguously the waveforms of gravitational waves—and perhaps even analyze them. ●

To probe further

Stephen Boughn's article, "Detecting gravitational waves," *American Scientist,* March-April 1980, Vol. 68, pp. 174–83, is an overview of the early work in the search for gravitational waves.

For a readable account of the binary pulsar PSR1913+16 and its role in providing evidence for gravitational waves, see *Was Einstein Right?* by Clifford M. Will (Basic Books, New York, 1986).

The Detection of Gravitational Radiation, edited by David G. Blair (Cambridge University Press, England and New York, 1991) sums up the state of the art in gravitational-wave receivers. It includes an introduction to quantum nondemolition detection.

The 1267-page textbook Gravitation, by Charles Misner, Kip S. Thorne, and John Wheeler (W. H. Freeman, formerly in San Francisco, now in New York, 1973), is still the bible of theory for students and practitioners in gravitational-wave research.

Chapter 10, "The Ripples of Curvature," in *Black Holes and Time Warps: Einstein's Outrageous Legacy,* by Kip S. Thorne (W. W. Norton, New York, 1994), summarizes plans for the Laser Interferometry Gravitational-Wave Observatory (LIGO).

For more on whether or not gravitational waves were detected along with the first sightings of the 1987 supernova, see "Coincidences Among the Maryland and Rome Gravitational Wave Detector Data and the Mont Blanc and Kamioka Neutrino Detector in the Period of SN1987A." Written by E. Amaldi, Joseph Weber, et al., it appears in the Proceedings of the 14th Texas Symposium of Relativistic Astrophysics, *Annals of the New York Academy of Sciences,* 1990, Vol. 571, pp. 561–76. Leonid Grishchuk refutes Weber's gravitational cross-section calculations in "Quantum Mechanics of a Solid State Bar Gravitational Antenna," *Physical Review D,* April 15, 1992, Vol. 45, no. 8, pp. 2601–08.

About the author

Melvin A. Lewis (SM) is senior staff engineer for the support equipment engineering department of Loral Electronic Systems Inc., Yonkers, N.Y. He has 31 years' experience in designing circuits and instrumentation systems for the defense industry.

perspective

When an entire system can be built on the periphery of a flat-panel display, a nation's ability to manufacture those displays becomes vital to the survival of its industries

U.S DISPLAY INDUSTRY ON THE EDGE

KEN WERNER
Contributing Editor

Later this month, display engineers and executives from around the world will congregate in Orlando, Fla., for the Society for Information Display's International Symposium, Seminar, and Exhibition (SID '95). Inevitably, they will agree that flat-panel displays are a commercially, militarily, and economically strategic technology. Inevitably, too, many of them will discuss the latest figures on where the displays are made, how market share is allocated among the diverse technologies, and above all, who is getting to spend the big bucks required for setting up manufacturing facilities for high–information-content flat-panel displays.

The general picture painted by these figures is familiar to the cognoscenti and of deep concern to members of the electronics industry in Japan, Korea, Taiwan, the United States, and Europe—although for different reasons. In Japan, which is investing heavily in flat-panel displays and dominates the world's high–information-content display market [see pie charts, opposite], industry leaders are confronting the inevitable erosion of their market share. Korean companies are investing the equivalent of hundreds of millions of U.S. dollars to seize a chunk of the market. Computer companies in Taiwan—badly burned in the first half of 1992, when Japanese suppliers rationed their allocation of liquid-crystal displays (LCD) modules and prevented them from filling many orders for laptop computers—are bent on achieving at least a degree of self-sufficiency in LCDs.

For a time, U.S. and European companies seemed not about to compete for the high-volume part of the flat-panel display business. The lead of Asian companies looked too great, and the investment needed for new manufacturing facilities is enormous. But perceptions change, and the current view is that if a region does not manufacture flat-panel displays, it will soon not manufacture a great many computer, communications, and consumer-electronic products as well.

Now, product planners look at electronic systems and see that, with the exception of the display, every component used today can either be miniaturized or replaced by one that can be. Even keyboards can be replaced in many applications by voice input, by electronic pens, or by "soft" keyboards presented on a touch-sensitive display.

Meanwhile, polycrystalline silicon is starting to replace amorphous silicon in the thin-film transistors that are basic to active-matrix LCDs. Once they have polysilicon to play with, designers can fabricate other circuitry—the drive, support, and even some system electronics—on the display's glass panel at the same time as they fabricate the active matrix's thin-film transistors [see "The shape of things to come," p. 65].

Once system electronics can be integrated with the display, the display effectively becomes the chassis and, moreover, the completed product. Consequently, anyone whose business currently involves importing a display and adding value to it—for instance, personal computer manufacturers—will no longer have a business, as there will be little value to add other than their brand name. In this context, the large investments some nations are making in flat-panel display manufacturing facilities (a high-volume manufacturing line costs in the US $300 million range, and entire plants well over half a billion dollars) are not surprising.

The other technologies

At the moment "flat-panel display" is almost synonymous with "liquid-crystal display." LCDs will account for 87 percent of all (not just high–information-content) flat-panel display sales in 1995, according to Stanford Resources Inc., San Jose, Calif. [see the pie chart, p. 64]. But there are certainly other technologies.

Electroluminescent displays, though a small percentage of the total, have a solid and loyal following. The world market for high–information-content electroluminescent displays is divided

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about 55:45 between Planar Systems Inc., Beaverton, Ore., and Sharp Inc., Osaka, Japan, according to Joel Pollack, product marketing engineer at Sharp Microelectronics Inc., in Camas, Wash. Planar Systems has developed an innovative full-color electroluminescent display for commercial use and is positioning itself for a broader range of applications. Sharp is at work in the laboratory on an entirely different approach to color, but emphasizes the electroluminescent approach for demanding monochrome uses, Pollack noted.

Plasma display panels, though they have more than twice the sales of the electroluminescent type, also have a small market. Still, they are the one direct-view technology that can produce large, flat, full-color displays and therefore almost certainly have a central role to play in large-screen high-definition television receivers. They are being worked on in Asia, the United States, and Europe, with Japan's Fujitsu Ltd. supplying the first commercially available full-color plasma display panel.

Field-emitter-display technology is still in a developmental stage, but some analysts think it is the only existing flat-panel technology that could compete head to head with LCDs. There is active development in France, the United States, and Asia.

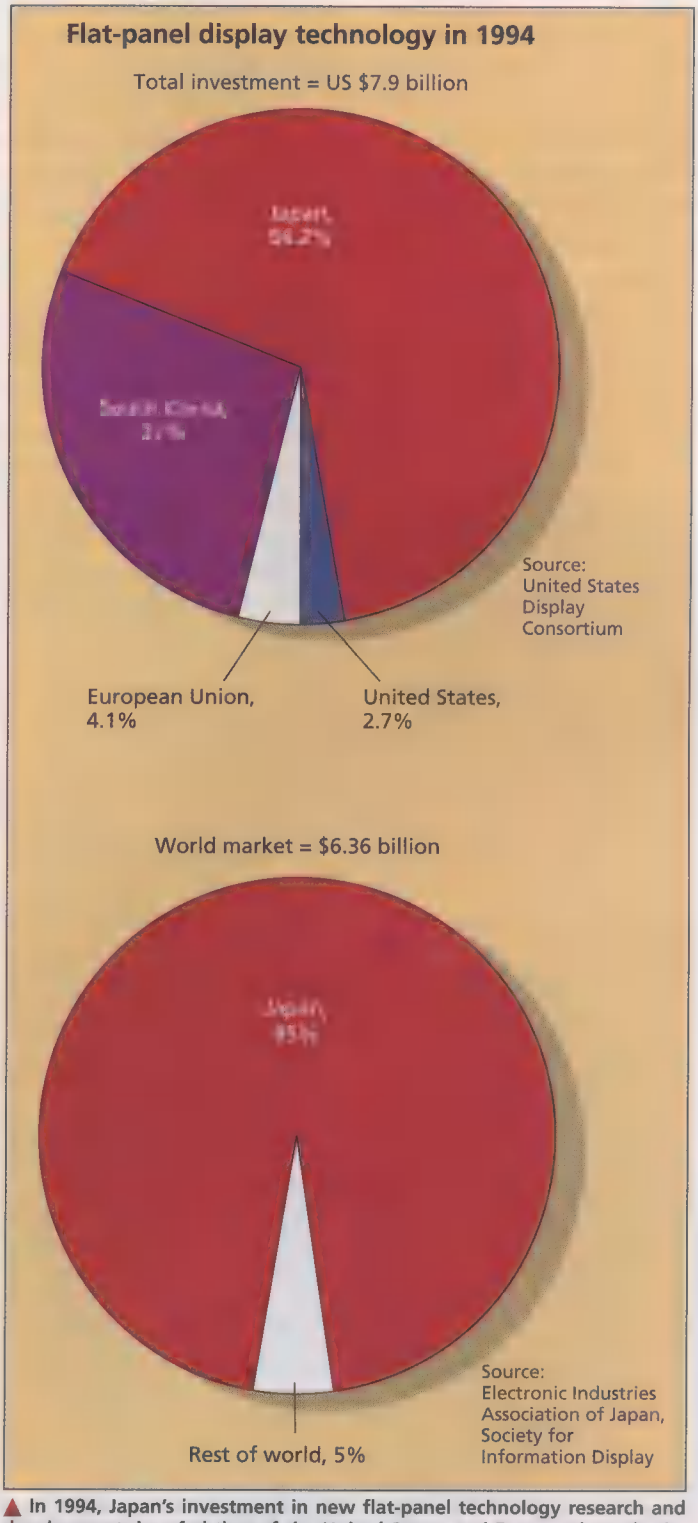
A national concern

In the United States, government as well as industry has good reasons to want an indigenous advanced display manufacturing industry. The Department of Defense (DOD), in particular, dislikes the idea of designing strategic systems around imported flat-panel displays. This concern is magnified by a business strategy shared by the major Asian suppliers of advanced displays, which is to produce standard items in high volumes and not bother with relatively small quantities of custom products.

The problem is, the existing U.S. flat-panel industry is minuscule—certainly too small to support the manufacturing equipment and material suppliers that make up the infrastructure an indigenous industry needs. But without the availability of such suppliers, each company would have to custom-design its own equipment, which small companies cannot afford to do. It's a classic chicken-and-egg dilemma.

The solution, as developed over the last few years, has industry-government consortia collaborating on both basic technology and a manufacturing infrastructure. The consortia will support and develop common manufacturing materials, processes, and equipment that can be utilized by most flat-panel display manufacturers. Because equipment makers will be able to sell these relatively standardized production tools to many manufacturers, they will have enough volume to keep prices affordable.

In general, the consortia are careful to be technology-neutral, and not try to outguess the market



ILLUSTRATIONS: MORRIS KHAN

▲ In 1994, Japan's investment in new flat-panel technology research and development dwarfed that of the United States and Europe; the only sizable effort that could be quantified was being launched by South Korea (figures for Taiwan are not available). Japan—with 95 percent of 1994's $6.3 billion world market for 10-inch–class (9.5–10.5 inches) flat-panels—was the only nation whose private industries could make such an investment unaided by government.

and pick winners in advance. (Fortunately, many generic manufacturing procedures, such as thin-film sputtering, photolithography, and handling large glass substrates, are common to all or many flat-panel technologies.) Seed money is coming from the industry itself, DOD and its Advanced Research Projects Agency (ARPA), and the Commerce Department's Advanced Technology Program.

The industry-government collaborations have energized the few U.S. producers of flat-panel displays, stimulated plans for new manufacturing efforts, and encouraged makers of semiconductor manufacturing equipment to invest in modifying their products extensively for the efficient production of flat-panel displays. Semiconductor Equipment and Materials International (SEMI), the trade association of semiconductor manufacturing-equipment and materials makers, started its North American Flat Panel Division in 1993. The division now has 103 members.

Another indicator is provided by the 33-year-old Society for Information Display, which in January 1994 held its first Display Manufacturing Technology Conference (DMTC). The organizers were pleasantly surprised when 500 people attended and equipment manufacturers complained that there were no associated exhibits. DMTC '95, held Jan. 31–Feb. 2, 1995, in Santa Clara, Calif., attracted 875 people and 52 exhibitors. Next February, it will be incorporated into Display Works '96, a larger event jointly sponsored by SEMI, the Society for Information Display, and the United States Display Consortium. Display Works will include a technical conference, business-development seminars, and an exhibition planned to include Asian as well as North American and European equipment makers.

Value subtracted

Not everything is coming up roses, however, as far as the flat-panel display crowd in the United States is concerned. The new leadership in the U.S. House of Representatives is targeting government-industry cooperative programs as part of its cost-cutting measures. These programs include some that were carefully crafted to enhance the DOD's ability to procure commercial technology for military applications. DOD is convinced this dual-use approach will allow it to procure systems far more efficiently and quickly than it has in the past. Other flat-panel programs on the chopping block are already building a commercial base that is generating tax revenues. Consequently, at least some people in DOD, the display community, and the Clinton administration are shaking their heads in wonder.

At DMTC '95, Kent H. Hughes, associate deputy secretary of the Commerce Department and past president of the President's Council on Competitiveness, said: "The new legislators need education. Some are skeptical of technology policy. They think it is similar to an industrial policy, which they think is one step away from a Soviet five-year plan. We think, though, we have an effective story to tell."

DOD's appeals so far have fallen on deaf ears, and the agency's representatives state publicly that they must not be explaining things clearly enough. Spokesman Glenn Flood said: "We're still fighting for...dual-use programs. We need to find ways of educating people about the dual-use concept and its importance to DOD and the country."

Aris Silzars, director of the Display Research Laboratory at the David Sarnoff Research Center, in Princeton, N.J., is privately circulating the draft of a position paper among senior people in the display community prior to wider distribution. Portions of the white paper obtained by *IEEE Spectrum* [see "Excerpts on display," p. 67] indicate just how important some people in the flat-panel display world believe these programs to be.

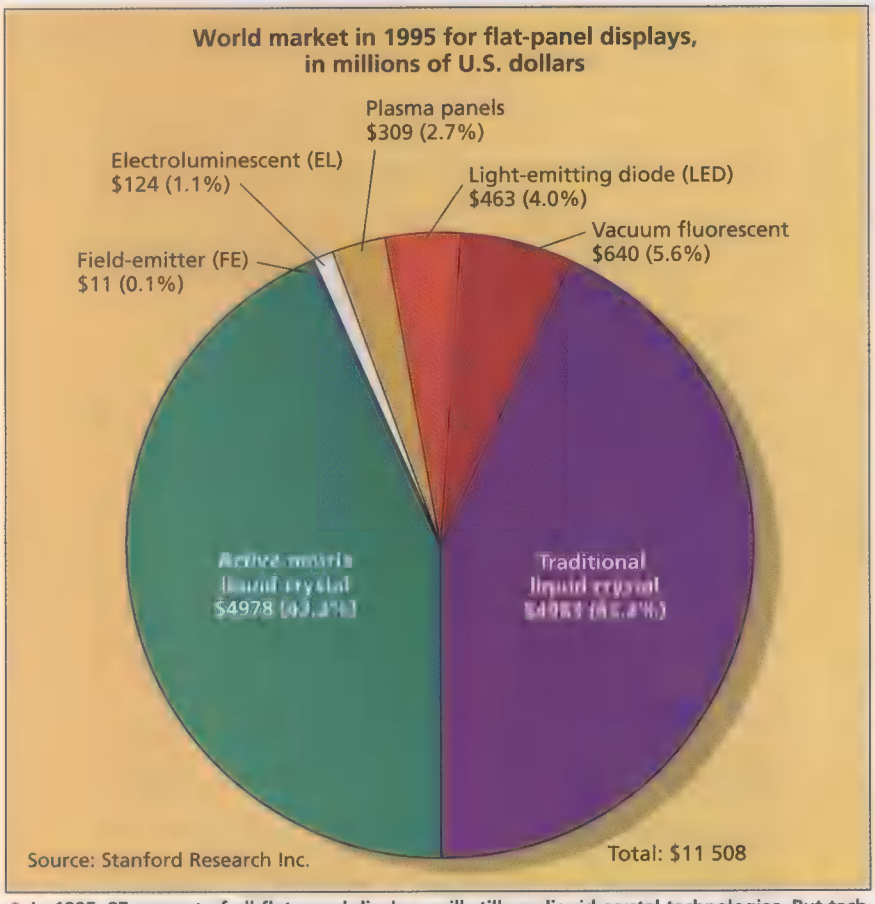
Meanwhile, DOD's Technology Reinvestment Program, which is dedicated to realizing the benefits of dual-use technology for military systems development, may be the first casualty of Congressional cost-cutters. Funding for the program has been cut from the current House and Senate versions of the appropriations bill.

Cast of players

Against this turbulent background, let's look at the leading consortia and support organizations. Who are the players, what are their roles, and how can companies gain access to some of the money and support services that are now available?

Founded in 1993 by ARPA and industry, the United States Display Consortium quickly emerged as a critical force in the renaissance of flat-panel display manufacturing in the United States. "The [consortium's] mission—developing a U.S.-based infrastructure of equipment and materials suppliers—is the bridge that will allow the domestic [flat-panel display] industry to make the transition from strong R&D to robust manufacturing," M. Robert Pinnel, the consortium's chief technical officer, told *Spectrum*.

Funds for the consortium come partly from DOD through ARPA and partly



In 1995, 87 percent of all flat-panel displays will still use liquid-crystal technologies. But technologies just coming on line, such as field-emitter and color plasma, can challenge them, thereby opening a window of opportunity for those who can afford the game's sizable ante.

from the industry itself. The first-year goal, that industry would fund 29 percent of the program, was exceeded—industry actually contributed over 50 percent.

The consortium's projects are defined by a technical council [see block diagram, p. 66] made up of representatives from member companies, which include AT&T, Motif, Planar Systems, Silicon Video, and Xerox PARC. Also included are representatives of the United States Display Consortium's commercial user group (Apple, AT&T, Chrysler, Compaq, Delco Electronics, IBM, InFocus, and Sun Microsystems), the military and avionics user group (which includes Litton Systems Canada, Rockwell, and SAIC), the supplier community, and the U.S. government.

For each project, a team of experts from the manufacturing members prepares detailed specifications for the next-generation system or process. These specifications are put in the form of a request for proposal that is distributed to the supplier community through SEMI's North American Flat Panel Division.

The suggestion that this arrangement compromises the openness of the process is dismissed by Bill Reed, SEMI's president. "SEMI had already established an efficient structure with the [Flat-Panel Division], which is as open a group as you could imagine. Any North American-based supplier of flat-panel display equipment or materials can join, including the North American divisions of Asian and European companies. In fact, our goal is that 100 percent of these companies will join [the division]."

After suppliers submit their proposals, the project team selects those they judge best and presents its recommendations to the technical council for approval. Upon doing so, the council sends the recommendations to the Governing Board for its approval and granting of awards. This three-level review process is intended to ensure that proposals are selected only on their business and technical merits.

Recent proposals include one for developing equipment and processes for photolithographic patterning of a large area—currently 500 by 500 mm—of display glass when the electrical and physical features do not require the very high resolution of stepper lithography. Another is intended to establish a competitive U.S. supply base for light-polarization and -retardation films, a critical and costly component in liquid-crystal displays.

So far, the United States Display Consortium has authorized 13 projects worth $51 million—a sum that includes both the ARPA and the consortium's awards and the industry's cost share.

The consortium has close ties with SEMI and the National Center for Advanced Information Components Manufacturing at Sandia National Laboratories. In

The shape of things to come

A hint of the future is apparent in one of today's commercial products: DisplayPac, from Computer Dynamics Inc., Greer, S.C. A complete computer, it is only slightly larger than its largest functional component—a color liquid-crystal display (LCD) with a 10.4-inch diagonal. The entire 486DX4 is 64 mm thick, and is intended for machine control and similar embedded applications.

As the photograph shows, the Computer Dynamics product is built on a conventional chassis, which is dominated by the LCD. It is now technically possible to mount many of the required ICs directly on the LCD's glass substrate with tape automated bonding or chip-on-glass technology. Chip-on-glass is particularly attractive because it permits dense packaging. Reality does rear its ugly head here. Many of the required chips are not available in a form compatible with chip-on-glass, and building a chip-on-glass computer would not be economically viable today. When it is viable, the LCD's glass substrate would be the primary chassis for the display, and the conductors connecting the chips would be part of the display substrate.

The next level of integration, as most commonly conceived, depends upon the replacement of amorphous silicon—the material currently used for making the transistors in active-matrix LCDs—with polycrystalline silicon. With this higher-quality material, display drivers and other relatively low-density electronics could be fabricated directly on the active-matrix LCD substrate when the display itself was made. At that point, the display would contain a good part of the system, and not be just its largest and (often) most expensive component. But even the chip-on-glass approach embodies system circuitry on the display substrate, so the display will no longer be a component of the kind conventionally aimed at original-equipment manufacturers.

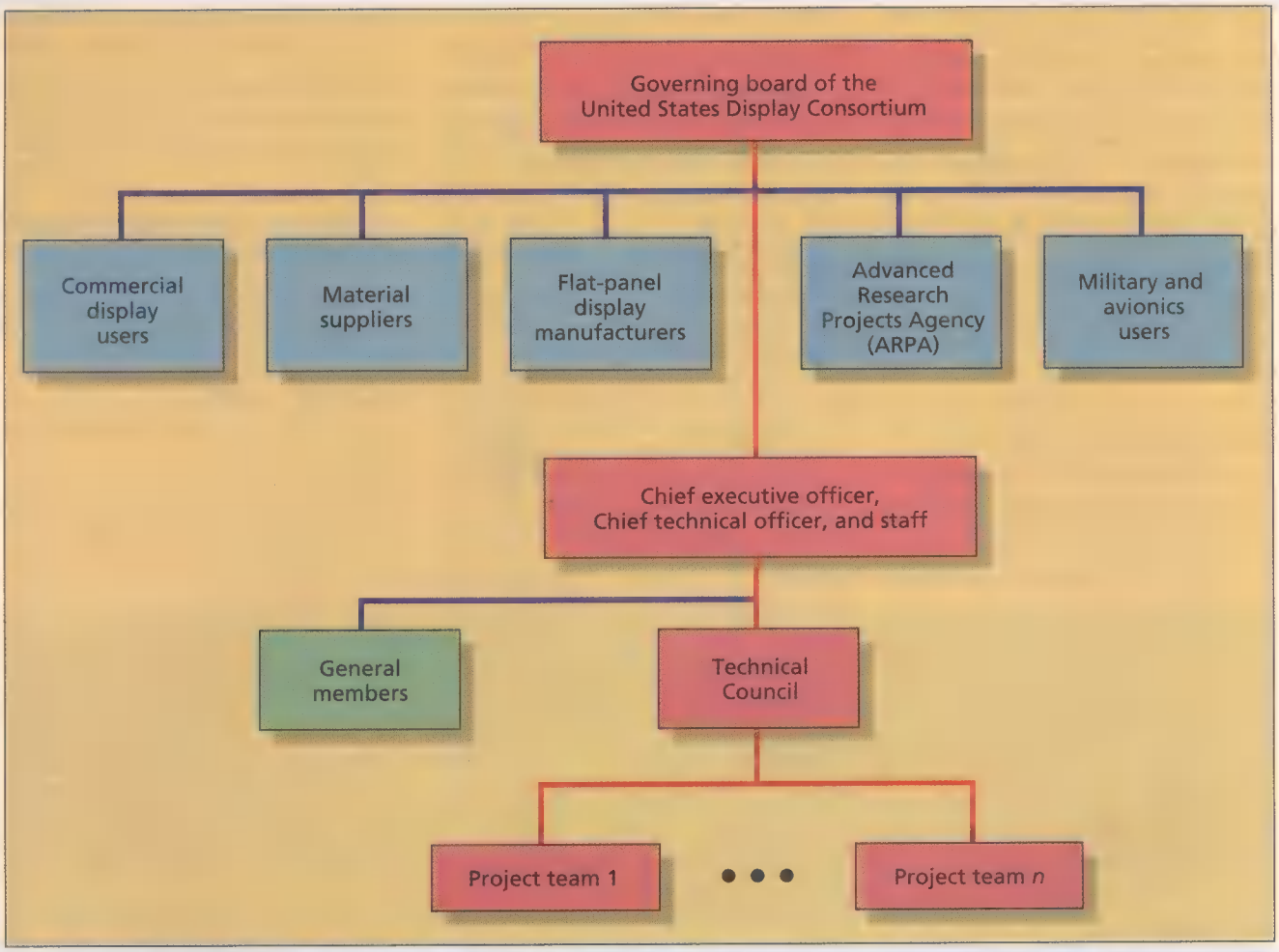
One company looking forward to using a glass-as-chassis architecture (of the chip-on-glass variety) is AT&T Corp., according to its vice president for global manufacturing and engineering, Lawrence C. Seifert. In the keynote address at the Society for Information Display's last International Display Research Conference, Seifert predicted that the home and office telephone of the future will be an inexpensive multimedia terminal plugged into an advanced broadband network. AT&T's current concept of such a terminal is an active-matrix LCD with chips around the display's periphery. These chips would not be limited to the display drivers, but would also include a 486-class processor, support chips, memory, disk controller, and local network interface. The LCD would be the chassis for the terminal, and most of the terminal's cost and size would be in the display.

"The display is the product," Seifert said last October in Monterey, Calif.

Polysilicon is being used now to fabricate small (2.5–5-cm) active-matrix LCDs for the next generation of LCD projection displays. It will be some time before the process can be economically scaled up to 10-inch (9–10.5-inch)-class displays. But papers that describe how integrated display drivers can be made with amorphous silicon will be presented at the Society for Information Display's International Symposium, Seminar, and Exhibition (SID '95) in Orlando later this month.

—K. I. W.





▲ **The United States Display Consortium makes sure that the selection of projects is unbiased by using a multitiered review path [shown in red].**

addition, it works with the other display organizations of importance. The five described here are the Society for Information Display, the Center for Display Technology and Manufacturing, the Phosphor Technology Center of Excellence, the National Center for Advanced Information Components Manufacturing, and the American Display Consortium.

The Society for Information Display (SID) is devoted to advancing display technology, manufacturing, and applications. Founded in the United States in 1962, the international nonprofit organization has 18 chapters in Europe, North America, and Asia. Its international technical conferences and exhibits are events at which issues having to do with business, as well as technology, have long been discussed.

Its largest conference of the year, the International Symposium, Seminar, and Exhibition (SID '95), will be held May 21–26 in Orlando, Fla. Display Works '96, which it sponsors together with the United States Display Consortium and SEMI, will be held next year, during Feb. 6–8, in San Jose, Calif.

The Center for Display Technology and Manufacturing at the University of Michigan was first funded in July 1993. The center focuses on research and development in manufacturing processes and materials, which the group's administrators believe are the keys to producing low-cost, high-quality displays.

Any for-profit company manufacturing displays, display components, or display materials in the United States may become a member of the center for an annual fee that, depending on the company's gross sales and location, ranges from $5000 to $50 000. (Michigan companies pay half the fee of out-of-state companies.) U.S. universities, research centers, and other not-for-profit organizations active in the field of high-definition or flat-panel-display technology are eligible for associate memberships at an annual fee of $5000. Members include Delco Electronics, IBM, and Philips Display Components, as well as the Georgia Institute of Technology and Kent State University.

With initial support from ARPA, the Phosphor Technology Center of Excellence set up its headquarters at Georgia Tech in August 1993, but it utilizes research facilities at several universities across the United States. It solicits the membership of for-profit companies and performs applied research, as well as supporting general research, on phosphors.

According to Aron Vecht of the University of Greenwich in England, display-phosphor research languished in the 1970s and '80s. Now, the research is catching up with other display advances, and the center is a worthy contributor.

As an example, the current interest in field-emitter displays has generated a need for low-voltage phosphors with improved performance. A paper presented at the Display Manufacturing Technology Conference '95 and written jointly by the Georgia Tech phosphor center and by personnel from SI Diamond Technology Inc., Austin, Texas, discussed the development of low-voltage phosphors with longer lifetimes and lower voltage thresholds. These phosphors can be run at higher current densities, resulting in displays with higher luminance and efficiency.

The National Center for Advanced Information Components Manufacturing (NCAICM, pronounced en-cake-um) was

Excerpts on display

The following passages have been taken from a privately circulated report written by Aris K. Silzars, director of the Display Research Laboratory at the David Sarnoff Research Center, Princeton, N.J.

• On the benefits of focused investments:

"Recently, there has been considerable discussion in Congress about replacing focused technology investments with across-the-board investment tax credits. Across-the-board credits may be useful but their benefits are hard to assess. On the other hand, we can already quantify the positive effect that the ARPA programs have had on leveraging modest investments. Private capital is available, but investors must be convinced that they are investing in something that is likely to become a business success. They are reluctant to put money into something that has not even been demonstrated in a laboratory. As with all of us, it's a 'show me something exciting' mentality. When ARPA provides its modest funding, in the few-million-dollar range, so a new technology can be demonstrated, this investment can result in private and institutional investors putting up the $10 million to $20 million (or more) needed to create a successful company. Real-world examples include Planar Systems, Inc. [Beaverton, Ore.]; Kopin Corp. [Taunton, Mass.]; SI Diamond Technology, Inc. [Austin, Texas]; and OIS Optical Imaging Systems, Inc. [Troy, Mich.]—and there are many others. Once this private investment has been triggered, and the company becomes a viable business, the government's investment is returned many times over. Planar, for example, is today a nearly $100 million corporation paying corporate income taxes, as well as personal income taxes through its employees. Is it not ironic that ARPA's focused-investment programs—proven money makers for the Federal, State, and Local Governments—are now being threatened under the banner of government cost-cutting?"

• On quantifying the payback of government investment:

"Programs such as ARPA's are not charities. They are the best return on investment the U.S. Government can hope to achieve. It takes between $2 million and $5 million government dollars to demonstrate a technology concept. Once demonstrated, that concept attracts $10 million to $20 million of private investment. In 5 to 10 years, the company grows to $100 million while additional private dollars are added to fund growth. All through this growth process the company has been adding employees and, at the $100-million level, is typically a 1000-employee company, with the government earning back over $30 million annually in corporate, personal, and social security taxes. This is a return on investment that any business would be proud to show. Even if only one business in five succeeds, it's still a great deal. The companies that grow large contribute substantially, but even those companies that stay small have attracted private investments, are employing people, and are creating a tax-paying base of skilled workers."

• On the effects of this investment:

"The U.S. can only succeed in being a leader in the Information Age if it can assure access to the best display technologies. Thus, the government's investment plays a surprisingly vital and multiplicative role. If we don't have the best displays, we lose this access, we lose our competitiveness in products using these displays—products such as computers, telecommunications, and semiconductors. The $100 million [per] year investment the government is currently providing begins to look like pocket change compared to the tax revenues that will be lost if the government turns its back on this already proven investment opportunity.

"We have good, modest, carefully crafted programs in place. They work. All we have to do is stick with those programs, nurture our entrepreneurs, and let American creativity and energy contribute to the wealth of the nation—and return the Government's investment many times over."

founded in the fall of 1993 at Sandia National Laboratories, in Albuquerque, N.M., to work with commercial and noncommercial organizations. Currently, projects include modeling flat-panel factory costs; laser alignment and the sealing of flat-panel display glass; vertical-cavity surface-emitting lasers; and contamination-free microelectronic manufacturing. The surface-emitting-laser project is generating commercial interest.

Since 1990, the American Display Consortium, Beaverton, Ore., has been developing generic pre-competitive technology—technology general enough to be jointly developed and shared by competing companies that differentiate their products at subsequent manufacturing stages. Projects include two National Institute of Standards and Technology programs valued together at $28 million: the development of high-density interconnects and panel-inspection systems; and the development of techniques for patterning flat-panel displays.

The American Display Consortium is also the industry representative on the phosphor center's executive steering committee. Consortium members include AT&T, Coloray, Electro-Plasma, Kent Display Systems, Motif, Norden, OIS, Photonics Imaging, Planar Systems, Plasmaco, SI Diamond, Silicon Video, Standish, Three-five Systems, and Xerox.

The other side of the Pacific

Taken together, the initiatives being mounted in the United States to simultaneously spark a flat-panel display manufacturing industry and the infrastructure needed to support it are proving remarkably effective, in spite of their relative infancy. For sure, the intensity of the debate might imply they are mammoth investments. Yet from an international viewpoint, the efforts are modest. Through late 1994, according to the United States Display Consortium, Japan's publicly announced production investment in flat-panel displays was US $4.9 billion, Korea's $2.0 billion, and Europe's $300 million. The U.S. outlay was only $200 million.

In Japan, the world flat-panel leader, the Ministry of International Trade and Industry (the Government's main arm for developing competitiveness) does not now have any major programs supporting FPD technology research or manufacturing, according to two sources: Masahiro Kosaka, director of Matsushita Ltd.'s Liquid Crystal Display Development Center in Osaka, and a second member of the display community who asked not to be identified. Recall, however, that Japan's share of the global flat-panel display sales, which today consists primarily of LCDs, was 95 percent in 1994; clearly, the industry has become large enough that one could reasonably expect it to be self-funding.

Given the investment being made in Korea and elsewhere, it is obvious that Japanese companies cannot maintain this market share, but how much erosion will Japan tolerate? Speaking last year at the 4th Annual Fine Process Technology Japan Conference in Tokyo, Tsuyoshi Kawanishi from Toshiba Corp., Tokyo, observed that LCDs will be even more important in the future. According to conference attendee William Bohannon of Manx Research, Escondido, Calif., some believe that Japan will always retain more than an 80 percent market share.

Matsushita's Masahiro Kosaka does not foresee any significant reduction in market

share through the end of the decade. Although the company does not estimate Japan's market for the longer run, another senior person stated that, while Japan's market share would necessarily decrease (although probably not to as little as 80 percent), the innovative, high-margin products would continue to come from Japan.

Elsewhere out East

Across the Sea of Japan, Korea is intent on making its mark in displays. Government aid is available, a multi-company project and a multi-company research organization have been set up, and more Koreans attend international symposia.

Most LCD production is currently in the older twisted-nematic and supertwisted-nematic types, but a thin-film transistor production line began operation just last year. Total 1994 sales of all types were about $150 million. Goldstar Electronics Co. and Samsung Electronics Co. expect to start producing thin-film transistor LCDs in 1995, followed by Orion, Korea Electronics, and Hyundai Electronics, according to Korea's Ministry of Trade, Industry and Energy as well as Myung-Hwan Oh, a professor at the Korea Institute of Science and Technology, and Sungkyoo Lim, an associate professor at Dankook University. The Korea Semiconductor Industry Association expects LCD production to hit $1 billion by 1997. That would be an estimated 8 or 9 percent of the world market—impressive in light of Japanese producers' 95 percent of today's market.

Industry and government have invested $700 million in building the factories that will produce those LCDs. As yet, no production plans for other flat-panel display technologies exist, but Samsung is pursuing joint development with Japan on plasma display panels, and Orion is pursuing plasma panel development with Russia.

The Korean ministries of Trade, Industry, and Energy; of Information and Communication; and of Science and Technology each have programs that make government loans available to approved projects at annual percentage rates of about 6.5–8 percent, up to a limit of 10 percent of the projected investment. At the R&D level, the Korean government has made a $20 million loan to a project for developing wide cathode-ray tubes (16:9 aspect ratio) with 16- to 36-inch diagonals. The companies involved include Goldstar, Korea Electronic Glass, Orion, Samsung, and Samsung Corning.

A multifaceted LCD project involving 14 companies has received a contribution of $6 million and a low-interest loan of $6 million.

The Electronic Display Industrial Research Association of Korea was set up in 1990 to represent display industries and jointly develop technology and standards; 28 companies are now affiliated.



Workers at Sharp Corp.'s Camas, Wash., facility assemble highly integrated active-matrix flat-panel displays. Japan's display manufacturers are now able to fund such facilities without government aid, and are investing heavily to ensure future competitiveness.

Korea has established an international cooperation policy, too. One element is a commitment to contribute more to worldwide display organizations, including the development of exchange programs and entering into joint and mutually beneficial R&D efforts. The policy recognizes Korea's position in the global display market. As the Ministry of Trade, Industry, and Energy sees it, Korea is strong in conventional production (with a global CRT market share of 25 percent), but is relatively weak in the development of new technology.

For their part, Taiwan companies produce more than half of the world's supply of computer monitors and a substantial number of notebook computers—nearly 1.3 million units in 1993.

Picvue Electronics Ltd. currently operates a production line of supertwisted-nematic LCD modules that are intended for hand-held games, word processors, and notebook computers. Nan Ya Plastic Corp. established a pilot line last year and will begin mass production by the end of this. The final targets of both companies are 10-inch VGA modules. Chunghwa Picture Tubes Ltd. finished construction of a supertwisted-nematic LCD pilot line in the first half of last year and has signed a cooperative agreement with Toshiba for the mass production of 10-inch supertwisted-nematic VGA LCDs.

Unipac Optoelectronics Inc. started producing thin-film transistor LCDs last year. Prime View International started construction of a high-volume thin-film transistor LCD plant in June 1994. Both companies intend to produce 10-inch-class color thin-film transistor LCDs.

Taiwan is strongly motivated to develop a respectable LCD manufacturing capability. "[Our] dependency [on Japan for LCD modules] caused a crisis in the industry when LCD module supplies ran short from Japan during the first half of 1992. In 1993, even though a total order [for] 1350 thousand notebooks was received, the Taiwanese manufacturers were not able to produce that much due to the shortage in LCD supply. The establishment of a local LCD industry is therefore indispensable for the Taiwan computer industry," said David C. Hsing of Taiwan's Industrial Technology Research Institute in prepared comments presented by H. Y. (Jim) Chen at this January's Display Manufacturing Technology Conference. Jim Chen is senior consultant in the design department of Chunghwa Picture Tubes' R&D Center and was the first president of the SID's Taiwan Chapter.

"While the size of LCD industry is relatively small right now," Hsing's comments continued, "the Taiwanese computer manufacturers believe that LCDs will play as the key to the Republic of China's future growth in the information industry. Public and private sector organizations are working together in cultivating fundamental LCD technologies, and are aware of the distance needed to be traveled before a solidly-built LCD industry can be achieved." Added Chen, "The government tries to help, but what it is able to offer is nothing like Japan."

Activity in Europe

In the European Union (known as the European Community through November 1993), the European Information Technologies Program (Esprit) is a sector of the European Research and Technology Development Framework Program (FWP).

Of the $16 billion budgeted under the fourth framework program (which runs from 1994 to 1998), $128 million is earmarked for display projects, according to sector head John Tsalas.

The lion's share—$108 million—funds a cluster of four tightly linked active-matrix LCD projects. Participants are the Flat-Panel Display Consortium (Philips, Merck, Sagem, and Thomson), 17 industries, 2 institutes, and 3 universities—all in 6 of the European Union countries. The main site of activity ("exploitation" in Esprit lingo) is the FPD Consortium's facilities in Eindhoven, the Netherlands. Main topics are materials, processes, manufacturing, equipment, standards, and application demonstrators.

As for the rest of the $128 million, the sum of $10 million is going to a two-year FED display project concluding by the end of this year. Participants are 10 industries and 2 institutes in 6 European Union members. Main exploitation is at the facilities of Pixel International SA, Montpellier, France. Finally, another $10 million is going to a two-year ferroelectric liquid-crystal display project, which is also scheduled to conclude by the end of this year. Participants are 5 industries and 2 universities in 4 countries of the European Union. Main exploitation is at General Electric facilities in the UK. Esprit is funding half the cost of all these projects.

In the balance

Andras I. Lakatos, president of SID, notes that the total of U.S. government and cooperative programs amounts to one seventh of Korea's investment, which is intended to capture less than 10 percent of the world LCD market. That raises the question of whether the current level of U.S. investment is adequate to earn the country the 15-percent market share targeted by the Department of Commerce.

U.S. optimists look at the Sematech organization and its role in reviving the U.S. semiconductor industry; the ability of Planar Systems to compete head to head with Sharp in the electroluminescent arena; the world-class innovations in flat-panel technology from the likes of Planar Systems, Xerox, Motif, Kopin, and SI Diamond; the high-level interest of large companies such as AT&T and IBM; and the success of some small U.S. companies in developing front-line equipment for Asian, as well as U.S., customers.

The optimists also point to the habits of U.S. investors, and emphasize the U.S. style is to kick-start an industry with relatively small investments. Once the engine starts turning, it will demonstrate its abilities and generate continuing investment from more traditional sources. Witness (they say) the enthusiasm already aroused by the existing programs and consortia.

By the time you read this, senior representatives of the display community will have come en masse to Washington, D.C., to tell their story to a sympathetic administration, a perhaps hostile House of Representatives, and a Senate whose leanings had not been well probed as this article was completed. The display community is hoping that Congressional opposition is a transient historical anomaly.

The programs, after all, are pro-business, and many small businesses are benefiting. They also have strong implications for U.S. trade, and they are strongly supported—many were initiated—by DOD. The agency regards them as the best (perhaps only) way to ensure the U.S. military has early access to the most advanced display technology at a far lower cost than traditional procurement methods would allow.

Can Congress rebuff these appeals? That will surely be another topic of conversation in Orlando. ●

Key U.S. flat-panel display organizations

Name	Contact	Address	Connections
American Display Consortium (ADC)	Christopher N. King, chairman	c/o Planar Systems Inc. 1400 N.W. Compton Dr. Beaverton, OR 97006	phone: 503- 690-1100; fax: 503-690-1244; e-mail: chris_king@planar.com
Center for Display Technology & Manufacturing	Michael E. Elta, executive director	University of Michigan 2360 Bonisteel Blvd. Ann Arbor, MI 48109-2108	phone: 313-763-0393; fax: 313-936-0347; e-mail: elta@umich.edu
National Center for Advanced Information Components Manufacturing (NCAICM)	James L. Jorgensen, director of NCAICM	Sandia National Laboratories M/S 0954, Department 2903 Albuquerque, NM 87185-0954	phone: 505-844-1023; fax: 505-844-5422 e-mail: jljorge@sandia.gov
Phosphor Technology Center of Excellence (PTCOE)	Christopher J. Summers, laboratory director	Georgia Tech Research Institute Georgia Institute of Technology Electro-Optics, Environment, and Materials Laboratory Quantum Microstructures Branch Atlanta, GA 30332-0861	phone: 404-894-3420; fax: 404-894-5073
Semiconductor Equipment and Materials International (SEMI) North American Flat Panel Display Division	Robin Hahn, manager of North American Programs	805 East Middlefield Rd. Mountain View, CA 94043-4080	phone: 415-940-6972; fax: 415-940-7916; e-mail: Rhahn@semi.org
Society for Information Display (SID)	Lauren Kinsey, executive director	1526 Brookhollow Dr., Suite 82 Santa Ana, CA 92705-5421	phone: 714-545-1526; fax: 714-545-1547; e-mail: socforinfodisplay@mcimail.com home page: http://www.display.org/sid
United States Display Consortium (USDC)	M. Robert Pinnel, chief technical officer	50 West San Fernando, Suite 920 San Jose, CA 95113	phone: 408-277-2400; fax: 408-277-2490; e-mail: !USDC@attmail.com

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Communication Network Architects

As ■ member of the technical staff, you will provide architectural guidance for advanced optical, wireless, and RF communication networks. You will interact with device technologists, digital designers, and software developers. Publication and research are expected. Requirements include PhD in Electrical Engineering or equivalent practical experience and familiarity with principles of digital communication theory.

RF Systems Designer

This person will be part of ■ team developing advanced communication systems – optical, wireless and RF. You will design RF engineering and specialized analog and high-speed digital systems. Requirements include MS or PhD in Electrical Engineering and at least 3 years' experience designing and building RF systems.

Interested candidates are invited to forward their resume and cover letter indicating position of interest to Rosemary E. Malvermi, MIT Lincoln Laboratory, Box IS5/95, 244 Wood Street, Lexington, MA 02173-9108. MIT Lincoln Laboratory is an equal opportunity employer, M/F/D/V. U.S. Citizenship required.

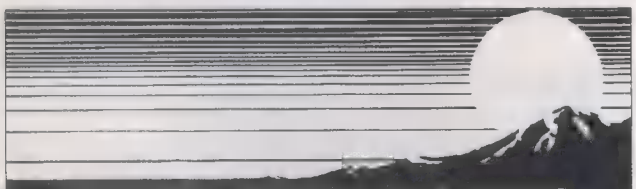
SOFTWARE ENGINEER

Loral Vought Systems Corporation is ■ major manufacturer of missile, rocket and space systems. The success of several programs has created exciting opportunities for entry-level and experienced engineers.

As software engineers ■ Loral Vought Systems, the successful candidates will develop real-time embedded software for guidance, navigation, weapon delivery, fire control, command control and communications, and other real-time weapons systems applications. A BS or MS degree in Computer Science, Engineering or Math and up to 7 years' experience in software design, code, test and documentation using Ada and DOD-STD-2167A is required. Familiarity with object-oriented methodologies or other software development technologies, Teamwork, ObjectMaker, FrameMaker or other CASE tools is highly desirable.

Loral Vought Systems offers a competitive compensation package that includes relocation assistance, ■ 9/80 work schedule with every other Friday off, and the option to purchase up to an additional week of vacation. Qualified candidates may be subject to security investigation for obtaining a DoD clearance and must meet U.S. Citizenship requirements. Please send resume to: **Loral Vought Systems, P.O. Box 650003, M/S LHR-PE, Dept. IEEE595, Dallas, Texas 75265-0003.**

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Q-DOT is ■ small, fast-growing R&D firm developing innovative data acquisition, signal processing and communication systems. Data acquisition programs include high speed (>5 Gs/s), low power (<1mW), and cryogenic designs. Signal processing systems target imagers/detectors, on-chip focal-plane processors, and large time-bandwidth equalizers for communications and medical applications. Communication programs include DDS systems and novel filters. Q-DOT has experienced substantial growth, and recent awards have again expanded our need for qualified designers eager to challenge and expand the state-of-the-art in signal processing products for new commercial markets. We have several positions currently open, with qualifications ranging from B.S.E.E. plus three years through M.S.E.E./Ph.D plus 3 years or better.

ANALOG IC DESIGN ENGINEERS will possess a B.S./M.S. E.E. plus two to five years' experience or better. You'll develop custom CCD/CMOS analog and mixed-mode signal-processing circuits from the device level up. A good grasp of device and circuit fundamentals is essential. Familiarity with Spice simulation and IC layout are also required. Analog/digital signal processing expertise is highly desirable.Test experience, RF/communications background ■ plus.

We offer an attractive salary and excellent benefits, including profit sharing and the opportunity to own stock. If you are seeking a challenging position with room to grow, send your resume to:

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GEORGIA TECH RESEARCH INSTITUTE

LABORATORY DIRECTOR

ELECTRO-OPTICS, ENVIRONMENT, AND MATERIALS LABORATORY (EOEML)

The Georgia Tech Research Institute (GTRI) is seeking a Director for one of its eight laboratory units. An individual is sought who can provide dynamic and creative leadership to a large diversified research organization in fulfilling its objectives in the areas of research, development, technical assistance and outreach, and technology transfer in ■ broad range of disciplines.

As ■ major, applied research component of the Georgia Institute of Technology, GTRI operates ■ $100 million a year program of analytical and experimental research in broad areas including aerospace, electronics, electromagnetics, materials, physical and chemical sciences, sensors, and transportation. The Electro-Optics, Environment, and Materials Laboratory (EOEML), with a staff of over 275 research, support, and student employees, performs research in (1) analysis, simulation, and testing of military and industrial electro-optical systems; (2) development of high-temperature materials, photonic materials, polymers and coatings, zeolites, and catalysts; (3) basic research in chemistry and atmospheric sciences; (4) research training, technical assistance, and technology transfer in environmental science, occupational safety and health, and manufacturing operations; (5) research, design, and development of opto-electronic devices, components, and systems; (6) and applied research in geographical information systems. EOEML's large and diverse research base includes both industrial and Government sponsors.

Candidates for the EOEML Director's position should have ■ Bachelor's or Master's degree in Engineering, Physics, Math, Science,or related field; a Ph. D is preferred. Ten or more years of experience in ■ leadership capacity with ■ specific technology orientation is essential, as well as ■ proven track record in contract development in industry, university or Government, and experience in the management of projects and services that promote new research thrusts and development of new markets. Candidates should possess a broad range of management skills in service, strategic planning, finance, and team building. The Candidate selected will be subject to a Government security investigation and must meet eligibility requirements for access to classified information. Experience in a university research environment is ■ plus.

Resumes should be sent to: **Chairman, Search Committee EOEML, Personnel Support Team, Georgia Institute of Technology, Georgia Tech Research Institute, 400 10th Street, Atlanta, GA 30332-0800.** Georgia Tech is an Equal Opportunity Affirmative Action Employer.

Georgia Tech



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-Antoine Laurent Lavoisier, 1743-1794,
Traite Elementaire de Chimie [1789]

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ATM R&D Engineer (Senior Engineer or Staff Engineer)
Communication specialist with an in-depth knowledge of ATM networks, AAL design and MPEG-2 adaptation issues. MSEE (PhD preferred).

System Engineer (Staff Engineer or Senior Staff Engineer)
Broadband telecommunication network system design, prototyping, integration, and testing, including SONET, ATM, AAL, MPEG-2, Q.2931 signaling, and B-ISDN/ATM standard. Project leading and hardware/ASIC experience, and network protocol knowledge. MS or PhD.

Software Engineer (Senior Engineer or Staff Engineer)
Broadband communication network protocol firmware and software design and implementation using C, Assembly, and DSPs; RISC processor writing real time software and microcode; familiarity with TMS320, Motorola 68xxx series and various Microprocessors. ATM, SONET, AAL, and TCP/TP knowledge. BS or MS.

Hardware/ASIC Designer (Senior Engineer or Staff Engineer)
Hardware/ASIC design experience using SONET/ATM protocols, and IC and board level specification, design, implementation and verification. Familiarity with XILINX or ACTEL FPGA, and VLSI design tools. BS or MS.

RF Circuit Designer (Project Engineer)
Senior position, linear and non-linear RF circuit design experience. Knowledge of one of the major RF CAD packages, basic commercial components, and fiber optic components and laser diode dynamics preferred. Minimum 7 years' experience. BSEE (MSEE preferred).

Fiber Optics Communications Engineer (Senior Engineer)
Experience designing RF circuits, hands-on design with laser diodes and external modulators, and one of the major RF CAD packages. A general understanding of limitations of real fiber optic communication systems. Laboratory skills. Minimum 3-4 years' experience. BSEE (MSEE preferred).

Fiber Optics Component Design Engineer (Senior Engineer)
Experience designing optical amplifiers and WDM systems for development of EDFA and/or PDFA optical amplifiers for CATV broadband video applications; knowledge of doped fiber, WDM components, pump laser reliability issues, and optimization of amplifier parameters. Minimum 3 years' industrial experience. BSEE and MSEE.

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Engineering



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DSP SOFTWARE ENGINEERS

Utilize your skills to assist in the development of new product definitions and applications; research, develop and simulate software algorithms for audio processing building blocks and implement them into real-time code; and conduct tests to verify and improve software programs.

Requirements include an MSEE or MSCE, experience with DSP code development, general structured programming skills using C or C++ programming language and assembly coding experience. The ability to understand concepts of a technical and mathematical nature and translate them into programming models for efficient DSP coding is essential. **DEPT. DSP.**

RF DEVELOPMENT ENGINEERS

Design, develop and test RF circuitry for wireless microphones and related RF systems.

Requirements include a BSEE or MSEE and at least 2 years of experience in radio frequency circuit design. Familiarity with antenna, audio and digital circuitry is preferred, but not required. **DEPT. RF.**

ACOUSTIC DEVELOPMENT ENGINEERS

The successful candidate has a Bachelor's Degree in Electrical Engineering or Physics and a minimum of 2 years experience in the development of acoustic or electromagnetic transducers. **DEPT. ADE.**

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We're CommQuest Technologies, Inc., a leading edge technology firm providing advanced wireless and satellite communications system solutions. Our state-of-the-art products provide cost-effective, highly integrated solutions to complex communication problems—solutions our commercial and government customers expect and depend upon. We are currently expanding our developments in cellular and PCS for domestic and international voice and data applications, as well as staffing for new and expanded satellite communication projects. We are seeking a number of individuals to add their talents to our software and hardware engineering teams. If you are a high performer with an entrepreneurial spirit and are interested in working for an employee-owned company, CommQuest is the place to be.

All positions require BSEE or higher degree, unless otherwise indicated.

RFIC DESIGN ENGINEER

This position requires 5+ years' experience performing detailed RFIC and/or MMIC design for low power wireless applications at 900MHz/1800MHz; familiarity with all phases of RFIC design; experience with design tools (such as CADENCE or MENTOR), and fabrication processes for high volume applications. Experience designing up/down converters, IF strips, frequency synthesizers, RF amplifiers, and understanding of design issues including figure, third order intermodulation problems, phase noise, gain distribution, and isolation are musts. Code: RDIC.

SOFTWARE ENGINEERS

These positions require 5+ years' experience in the development of Demand Assign Multiple Access (DAMA) software for satellite communication applications and/or communication protocol software for wireless applications. Working knowledge of C++ and embedded system development experience required. Familiarity with DSP and communication theory a plus. Code: SWE.

MICROCODE ENGINEERS

Selected individuals will have 5+ years' experience in the development of microcode for low level hardware control and interface applications. Must be able to perform instruction set definition, state machine design, and timing analyses, and to develop hardware sequencing microcode to be embedded in an ASIC. Familiarity with DSP and communication theory preferred. BSEE required, MSEE preferred. Code: MIE.

SENIOR DIGITAL DESIGN/ASIC DESIGN ENGINEERS

This position requires 5+ years' experience designing and implementing state-of-the-art ASIC based solutions for wireless communication applications. Working experience in digital signal processing and communications systems required. Knowledge of VHDL and ASIC design methodology preferred. Familiarity with Synopsys, Model Technology, IKOS Voyager, ORCAD and/or equivalent CAD tool experience is desirable. Code: SDD.

ASIC LAYOUT AND FABRICATION SPECIALIST

This specialist must have 5+ years' experience in performing layout and fabrication of high volume, low power ASIC applications. Applicant must have working experience with CAD tools such as MENTOR, COMPASS, ASPEC, or equivalent tools and extensive knowledge of the full ASIC development process, including layout, scan, verification, wafer probe, packaging, and test for sub-micron CMOS high speed implementations. Code: ALFS.

PROJECT ENGINEER

This professional will lead and manage multi-discipline (hardware, software, RF, etc.) engineering teams through all phases of product development and transition to manufacturing. Individual must have 8+ years' experience managing project teams of 10 or more engineers in the development of communication system products. Technical background and experience in the development of commercially marketed communication system products required. Code: PE.

SYSTEMS ENGINEERS

Selected individuals will have demonstrated skills in channel modeling, algorithm design, fixed point processing effects, and simulation with respect to hardware and software implementation limitations. Must have experience with GMSK and PSK modulations and their performance in fading channels, tracking loop design, adaptive filters/equalizers, filtering requirements, coding techniques, and TDMA and FDMA waveforms. MSEE or greater required. Code: SYE.

RF DESIGN ENGINEER

Selected candidate will have 5+ years' recent experience performing detailed RF/radio circuit design for low cost commercial wireless applications. Must have a good understanding of wireless radio architectures, modulation formats, currently available low cost RF discrete and integrated circuit components, and experience with RF design/simulation/analysis SW tools. Familiarity with SATCOM radio design requirements is a plus. Code: RFDE.

We offer competitive wages and benefits, company equity, excellent tools and facilities. For immediate, confidential consideration, e-mail your resume to careers@cqt.com; fax to (619) 633-1677; or mail to Professional Staffing-IEEE, Code (see above), CommQuest Technologies, Inc., 527 Encinitas Blvd., Encinitas, CA 92024-3740. Equal Opportunity/Affirmative Action Employer M/F/D/V.

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Continued from p. 18E4

Air Force Base, Ohio; Gary Dale, WL/FIME, 2145 5th St., Suite 1, Wright-Patterson AFB, OH 45433–7005; 513-255-6034; fax, 513-476-7652; e-mail, dalega@wl.wpaft.af.mil.

Power Engineering Society Summer Meeting (PE); July 23–27; Portland Hilton and Portland Marriott Hotels, Oregon; Glenn R. Meloy, 3660 S.W. Olson Court, Lake Oswego, OR 97034; 503-638-7018.

International Microwave and Optoelectronics Conference (MTT); July 24–27; Rio Palace Hotel, Rio de Janeiro, Brazil; Flavio J. V. Hasselmann, Rua Marquis de São Vicente, 225 22453–900 Rio de Janeiro, Brazil; (55+21) 529 9254 or 9450; fax, (55+21) 294 5748.

Vehicular Technology Conference—VTC (VT, Chicago Section); July 26–28; Hyatt Regency Chicago O'Hare Hotel, Rosemont, Ill.; Anthony Krueck, 8725 W. Higgins Rd., Suite 900, Chicago, IL 60631; 312-399-5168; fax, 312-399-7325.

Vacuum Microelectronics Conference (ED); July 30–Aug. 4; Portland Marriott Hotel, Oregon; Judith A. Sjoberg, Professional Association Management, 1201 Don Diego Ave., Santa Fe, NM 87501; 505-989-4735; fax, 505-989-1073.

Intersociety Energy Conversion Engineering Conference (ED); July 31–Aug. 4; Buena Vista Palace Hotel, Orlando, Fla.; D. Yogi Goswami, Solar Energy & Energy Conversion Laboratory, 220 MEB, University of Florida, Gainesville, FL 32611–2050 904-392-0812; fax, 904-392-1071.

august

Cornell Conference on Advanced Concepts in High Speed Semiconductor Devices and Circuits (ED); Aug. 6–9; Cornell University, Ithaca, N. Y.; George N. Maracas, Department of Electrical Engineering, ERC-154, Arizona State University, Tempe, AZ 85287–5706; 602-965-2562; fax, 602-965-0775.

International Conference on Intelligent Robots and Systems—IROS '95 (IE, RA); Aug. 6–9; The Westin William Penn, Pittsburgh; K. Ikeuchi, School of Computer Science, Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, PA 15213; 412-268-6349; fax, 412-268-6704; e-mail, ki@cs.cmu.edu.

International Workshop on Memory Technology, Design and Testing (C); Aug. 7–8; Hilton Hotel and Towers, San Jose, Calif.; Rochit Rajsuman, Department of Computer Engineering and Science, Case Western Reserve University, Cleveland, OH 44106; 216-368-5510; fax, 216-368-2801; e-mail, rajsuman@alpha.ces.cwru.edu.

Summer Topical Meetings: Technologies for a Global Information Infrastructure (COM, LEO), Aug. 7–9; **Flat Panel Display Technology**

Continued on p. 70E4

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Product Design Engineers

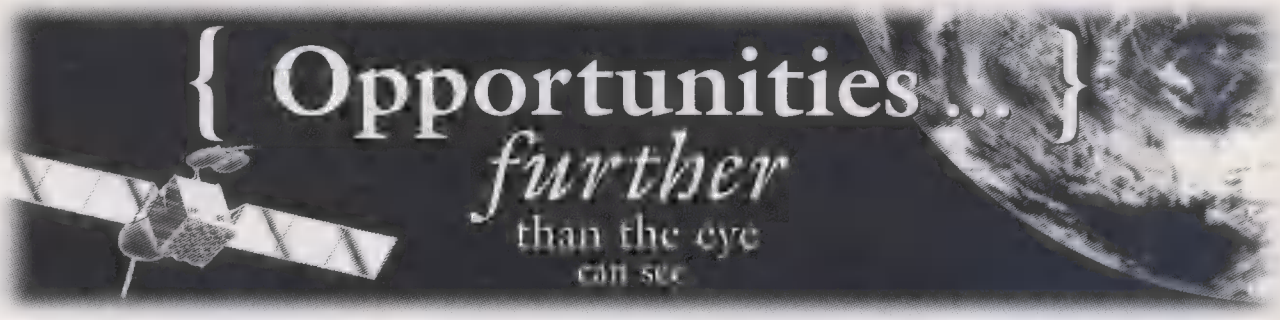
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Sr. Electrical Engineer

Working within the advanced electronics development group, this individual will participate in the application of the latest technology supporting Bose Corporation's future success. This group of OEM is charged with developing new product concepts incorporating RF, DSP and digital communication techniques. The initial focus of this position will be the refinement of existing signal processing algorithms and the evaluation of current system performance. Long term responsibilities include continuing the development of enhanced signal processing and advanced systems for future products. The ideal applicant will have an MSEE and a minimum of 5 years' experience developing and implementing communications/signal processing algorithms on fixed-point programmable DSP chips. Familiarity with modern radio receiver architectures and circuitry is required.

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HSC currently has a variety of projects in both the ***government*** and ***commercial*** sectors, which affords individuals the opportunity to branch into exciting new technologies and broaden their skills. And, with a backlog of work resulting from major contract wins and the commercial popularity of our ***HS 601*** communications satellite, HSC is poised to offer outstanding growth potential and future success in any of the following areas:

SYSTEMS ENGINEERING **(Job Code: A)**

Responsible for providing analysis, signal processing, waveform acquisition, interface and environmental definitions, design requirement definition and specification flowdown, system integration and test of the next generation of wireless telecommunication systems. Requires 2 years of analog and digital experience and ■ BSEE or MSEE specializing in communications systems theory.

MICROWAVE CIRCUIT DESIGN **(Job Code: B)**

Working to develop the heart of the global telecommunications infrastructure, these individuals will utilize the latest CAE tools such as LIBRA, Ansof and SONNET to model and analyze circuit and unit designs from 100MHz to 20GHz. Breadboarding and test experience is essential. Satellite communications payload hardware design experience is preferred, specializing in amplifier, mixer, filter and oscillator design. Requires 2 years of experience and ■ BSEE.

RECEIVER/SYNTHESIZER DESIGN **(Job Code: C)**

These positions will work on microwave communications receiver/ synthesizer design for the world's first direct-to-hand held phone system. Your experience in PLL, DDS, Spread Spectrum, VSAT and Modem design will aid you in leading a team of engineers to develop the next generation of wireless telecommunications systems. Individuals must be self-starters capable of taking a concept from development through production. Requires 5 years of experience and ■ BSEE.

POWER SUPPLY DESIGN **(Job Code: D)**

Responsible for new development on high-voltage power supplies for travelling wave tube amplifiers, very high efficiency low-voltage power supplies and similar products. Qualified individuals will have experience with design reviews and interfacing with customers, subcontractors and suppliers; strong analysis skills; design for manufacturability and assembly skills; ■ strong background in components and their failure mechanisms; and proven failure and reliability analysis skills. Requires 3 years of experience with high and low-voltage power supply design.

DIGITAL COMMUNICATION SUBSYSTEM ENGINEERS **(Job Code: E)**

These positions will develop unique, innovative DSP-based digital communication onboard processors using advanced technology. EHF communication system experience is desirable. Responsible for providing technical leadership, customer interface, requirement definition and flowdown, communication simulation/analysis, detailed design verification, and integration and test. Requires 6+ years of applicable experience and an MSEE in Digital Communication Theory, with emphasis in digital signal processing or equivalent.

SATELLITE COMMUNICATION SYSTEMS ENGINEERS **(Job Code: F)**

Responsible for performing system and payload architecture definition and design, including requirements development, flowdown and verification. Requires experience in preparing proposals and design reviews. Understanding of MIL-STD-1582 and 1810 waveforms or commercial communications and networking standards also beneficial. A BSEE or MSEE is desirable.

I.F. CIRCUIT AND ANALOG ASIC DESIGN ENGINEERS **(Job Code: G)**

Individuals are responsible for requirement definition, architectural and detailed design, simulation, worst case analysis, design development and test. Qualified candidates will have 3 or more years of experience in I.F. circuit and analog design (up to 1 GHz), using appropriate CAD tools. Experience with utilizing high-speed and performance analog to digital converter devices is very desirable; digital communication equipment design and low-level signal design experience is ■ plus. A BSEE or MSEE is preferred.

DIGITAL CIRCUIT AND DIGITAL ASIC DESIGN ENGINEERS **(Job Code: H)**

Individuals are responsible for requirement definition, architectural and detailed design, simulation, worst case analysis, design development and test. Digital circuit and digital ASIC design involves DSP arithmetic processor design. Qualified candidates will have 3 or more years of experience in digital circuit and digital ASIC design using appropriate CAD tools. Digital communication equipment design and a BSEE are very desirable.

SATELLITE SYSTEM ARCHITECTS **(Job Code: I)**
COMMUNICATION SYSTEM ARCHITECTS **(Job Code: J)**

Positions are responsible for developing the innovative concepts that will maintain our industry leadership into the next century. This involves evaluating customer needs and market opportunities, concept formulation, and top-level trade studies.

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For immediate consideration, please send your resume indicating the appropriate Job Code to: **Hughes Space and Communications Company, Staffing Dept., Job Code: _____, Dept. 124-IS-PW, Bldg. S10, MS S368, P.O. Box 92919, Los Angeles, CA 90009.** FOR MOST POSITIONS, applicants selected will be subject to ■ security investigation and must meet eligibility requirements for access to classified information. Proof of U.S. Citizenship may be required for some positions. We are an Equal Opportunity Employer.

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Wednesday, May 17
5:30 - 8:00 P.M.
Heritage Inn
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Orlando, FL

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Hughes Space and Communications Company

calendar

Continued from p. 70E2

(LEO), Aug. 7–9; **ICs for New Age Lightwave Communications** (LEO), Aug. 9–11; **RF Optoelectronics** (LEO), Aug. 9–11; Keystone Resort, Keystone, Colo.; Samantha Phillips, IEEE/LEOS, 445 Hoes Lane, Box 1331, Piscataway, NJ 08855–1331; 908-562-3894; fax, 908-562-8434.

Autotestcon '95 (AES, IM, Atlanta Section); Aug. 7–10; The Inforum, Atlanta, Ga.; Michael Kelley, Lockheed Aeronautical Systems Co., Marietta, GA 30063–0232; 404-494-3844; fax, 404-494-6151.

Non-Volatile Semiconductor Memory Workshop (ED); Aug. 13–16; Hyatt Monterey Hotel, California; Rustom Irani, WSI, 47280 Kato Rd., Fremont, CA 94538; 510-498-1729; fax, 510-657-8495.

ENGINEERING OPPORTUNITIES

Westinghouse is the leader of electrical energy technology. We are seeking Engineers to continue in our tradition of excellence, as we guide the world to brighter tomorrows. With an excellent reputation and forward-thinking approach, there's no limit to our opportunity. Join us at our Westinghouse Power Generation Headquarters in beautiful Orlando, Florida, in the following available positions:

Various opportunities for entry level to senior level mechanical and electrical engineering positions exist within our Steam Turbine and Generator organizations:

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Requirements include a BS in Mechanical Engineering, along with experience in steam turbine, generator or exciter design, service and/or project management. Responsibilities will include mechanical designs of turbines, generators and exciters; service and support to field engineers; project leadership for programs; and heat transfer, thermal analysis and field flow calculations.

Electrical Engineers

Requirements include a BS in Electrical Engineering, along with experience in steam turbine, generator or exciter design, service and/or project management. Responsibilities include electrical design of generators and exciters; service and support of field engineers; application engineering of steam turbines or generators and exciters; project leadership for related programs; application engineering for power electronic inverter based products; power electronic design and control system design.

Materials Engineers

Several opportunities currently exist in the Materials Engineering areas, including Metallurgical Engineers - Superalloys; High Temperature Coating Engineers - Thermal Barrier Coatings; Ceramic Engineers - Ceramic Mix Composins; Metallurgical Engineers - Ferritic and Acstenitic Alloys; and Electrical Insulation Engineers. Successful candidates should possess a minimum of 5 years of related experience, along with a familiarity with the manufacturing process, development, test and inspection techniques for power generation applications. An advanced degree and the demonstrated ability to plan and execute major developmental programs are preferred.

Engineering Computer Methods Architect/Specialist

Requirements include a BS in Mechanical Engineering/Computer Engineering or equivalent; experience with mechanical design practices or numerical computing methods; and knowledge of Modern Engineering Computer Systems, to include general purpose mechanical geometric design and analysis codes. A working knowledge of FORTRAN and C programming languages and the UNIX operating system also necessary.

Strong computer skills will be considered a plus for any of the opportunities listed above.

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Westinghouse

International Symposium on Electromagnetic Compatibility (EMC); Aug. 14–18; Atlanta Marriott Marquis, Atlanta, Ga.; All About Meetings, 2301 Artesia Blvd., Suite 12–101, Redondo Beach, CA 90278; 310-371-3438; fax, 310-371-5268.

International Conference on Solid State Devices and Materials (ED, Tokyo Section); Aug. 21–24; International House Osaka, Japan; SSDM '95 Secretariat, Business Center for Academic Societies Japan, 5–6–9 Honkomagome, Bunkyo, Tokyo 113, Japan; (81+3) 5814 5800; fax, (81+3) 5814 5823.

Third International Conference on the Applications of Diamond Films and Related Materials (ED); Aug. 21–24; National Institute of Standards and Technology, Gaithersburg, Md.; Albert Feldman, NIST, A329 Materials Building, Gaithersburg, MD 20899; 301-975-5740; fax, 301-990-8729.

Asia Pacific Design Automation Conference (CAS); Aug. 29–Sept. 1; Nippon Convention Center, Makuhari, Japan; Tatsuo Ohtsuki, Department of Electronics and Communication Engineering, School of Science and Engineering, Waseda University, 3–4–1 Okubo, Shinjuku-ku, Tokyo 169, Japan; (81+3) 3203 4141; e-mail, ohski@jpwasoo.bitnet.

International Symposium on Compound Semiconductors (ED); Aug. 29–Sept. 2; Shilla Hotel, Cheju Island, Korea; Yoon Soo Park, Office of Naval Research, 800 N. Quincy St., Arlington, VA 22217–5660; 703-696-5755; fax, 703-696-2611.

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International Conference on Simulation of Semiconductor Devices and Processes (ED); Sept. 6–8; University of Erlangen-Nurnberg, Erlangen, Germany; Heiner Ryssel, Universität Erlangen-Nurnberg, Lehrstuhl für Elektronische, Bauelemente, Cauerstr. 6, D-91058, Erlangen, Germany; (49+91) 3185 8633; fax, (49+91) 3185 8698.

Petroleum and Chemical Industry Technical Conference—PCIC '95 (IA, Denver Section); Sept. 10–14; Sheraton Denver Technical Center, Colorado; John Nelson, NEI Electric Power Engineering, Box 1265, Arvada, CO 80001; 303-431-7895; fax, 303-431-1836.

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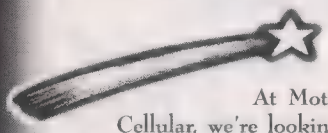
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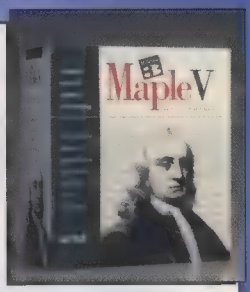


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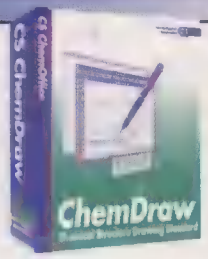
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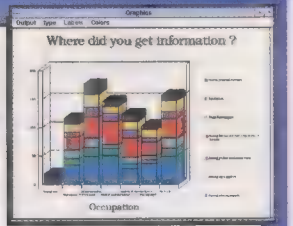
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program notes

Two approaches to client-server systems

JOHN R. HINES

The recent flood of articles and seminars about client-server computing indicates the growing popularity of this architecture for storing, manipulating, and viewing data. Its strength lies in its ability to distribute tasks, which gives the approach a booster shot of computing power. Neither the centralized computing of the 1970s nor the local computing of the '80s can compare for efficiency.

When a centralized system is used for a task such as database management, a single general-purpose mainframe or minicomputer handles every task except one—the display of the machine's output is left to attached terminals. In a local system used for such tasks, ordinary PCs manipulate as well as display stored data; the data may be stored on the local PC itself or a shared file server.

Client-server computing adds yet more intelligence, and specialized intelligence at that. In the interval between being stored on a file server or large computer and being finally processed and viewed on PCs, the data is preprocessed on an application server—either a specialized computer or software—dedicated to accessing and manipulating data.

The application server is undoubtedly efficient. It sorts through large masses of data and passes only relevant information to the local computer. It is much faster than a large multi-user computer or a local PC at juggling data because it is optimized for a single task. Since it transmits only relevant data, fewer bytes are moved over the network, thereby freeing up bandwidth.

Two models of client-server computing have emerged, and both are typically used to upgrade pre-existing systems to client-server status. Right-sizing (formerly called down-sizing) reshapes a database management system based on a large computer, while up-sizing does the same for one based on PCs.

Right-sizing is a three-layered environment: data on the database server (layer one—a workstation, minicomputer, mainframe or even a supercomputer) is preprocessed on separate application server hardware (layer two) before being passed on to the individual user's computer (layer three). Up-sizing is a two-layered structure; data resides on, or is moved to, a network server (layer one), which also preprocesses data using application-server software before sending it to a local computer "client" (layer two).

In effect, the right-sizing adds a computer to further distribute computing tasks, while up-sizing adds computing ability to make them more centralized.

Opening up databases

Down the years, database management systems have accessed data by means of one of three types of techniques. Most older mainframe databases, for instance, find data through an index-based technique implemented in a language like virtual sequential access method (VSAM). Modern PC-based systems lean toward navigation techniques, using languages like dBASE to store data in records. And many modern minicomputer databases rely on data relationships, with information being stored in the rows and columns of tables and the relationships between tables being clearly stated.

A structured query language (SQL) is the usual way of implementing the relationship-based technique. But while SQL has been represented as a generic interface to all relational database management systems, it has at least three dialects. Worse, there are two unique and incompatible ways to implement systems based on the language. Embedded SQL appends SQL code to the source code of the database management system. Call-interface SQL supplies an interface to a stand-alone SQL.

The X/Open Group and the SQL Access Group addressed the problem in 1992 by proposing the call-level interface standard (CLI 1992), a generic interface for accessing database management systems. The most popular implementation of the standard is Open Database Connectivity (ODBC), a programming interface that is part of Microsoft's Windows Open Systems Architecture.

This generic software is supplied as a Windows dynamic-link library. With it and the proper driver, any application that complies with the Open Database Connectivity interface can communicate with a similarly compliant database management system. The applications make calls to the Open Database Connectivity interface, and the driver translates them into a format the database system recognizes. It is up to the vendors of that type of system to make their products compliant with the interface and to supply the right driver.

The paper, "ODBC: Getting Connected," goes into more detail. *For copies contact: Intersolv DataDirect, 1800 Perimeter Park Dr., Suite 210, Morrisville, NC 27560; 919-461-4200 (800-876-3101 in the United States)* or **circle 120**.

Back to its future

Following the sale of assets related to its spreadsheet and personal information managers to other companies, Borland is repositioning itself. It is again concentrating on programming tools, but this time as a client-server specialist, offering up-sizing and scalable programming tools. The up-sizing tools generate application server and local PC applications for Windows, Windows NT, and Windows 95. The scalable tools let programmers quickly modify applications to work with both local PC and SQL database management systems.

Two recently released client-server development tools are Delphi and Borland C++ with Database Tools. Both contain the Database Engine and SQL Tools, libraries built with object-oriented technology. The Database Engine's object classes (for Borland's C++ and Object Pascal) let applications talk to dBASE or Paradox databases, or those compatible with the Open Database Connectivity interface. SQL Tools supplies similar classes for SQL-compatible servers.

Borland C++ with Database Tools is for programmers developing high-performance C++ client-server applications. It is the latest version of the company's C++ compiler, coupled with Database Engine, SQL Tools, and a pre-release version of Borland's ObjectComponent Framework. The framework's classes ease the development of OLE 2.0-compatible client and server applications.

Delphi is a visual tool for rapid application development, and those who have had a chance to use it are impressed. Based on Object Pascal, it comes with all the tools needed to build solid object-oriented client-server applications, and it ships with Database Engine and SQL Tools, too. *Contact: Borland International Inc., 100 Borland Way, Scotts Valley, CA 95067; 408-431-1000; or* **circle 121**.

Contributor John R. Hines is a silicon sensor engineer at Honeywell Inc.'s Microswitch Division, Richardson, Texas.

Consultants: Bruce Mather, *Phototelesis Corp.*; Shari L. Pfleeger, *Systems/Software Inc.*

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Yale University - Electrical Engineering/Computer Science: The Department of Electrical Engineering, in cooperation with the Department of Computer Science, invites applications for two faculty positions in the area of Computer Engineering. One of these will be at the level of full professor, and the other is at a lower rank. Applicants should have a Ph.D. in Electrical Engineering, Computer Science, or closely related field, and should exhibit outstanding research accomplishments and ■ commitment to teaching. The candidate for the full professor position must be a recognized leader in his (her) field. Research in such topics ■■ interactive system architecture, distributed computer system and network architecture, special-purpose computer architecture, high assurance computer systems for various critical applications, algorithm design for VLSI and ASIC applications, and related software engineering will be considered. Close collaboration with the existing Computer Engineering group is expected. Preferred candidates are U.S. citizens or have ■ permanent resident visa. Women and members of minority groups are especially encouraged to apply. Please send curriculum vitae, including names, addresses, telephone numbers, and email addresses (if available) of at least three references (at least 8 for the senior candidate), to Professor T.P. Ma, Chair, Department of Electrical Engineering, Yale University, 15 Prospect Street, New Haven, CT 06520-8284. Applications are accepted up to May 31, 1995. Yale University is an affirmative action, equal opportunity employer.

Chairperson, Department of Electrical Engineering, Texas Tech University: Nominations and applications are invited for the Chairperson of the Department of Electrical Engineering at Texas Tech University. The Chairperson is expected to lead the department in the continued development of high quality undergraduate and graduate programs in electrical engineering. The department currently has approximately 350 undergraduate (B.S.) students and 65 graduate (M.S. and Ph.D.) students, with 21 faculty, 6 staff, and approximately $3.7 million in funded research. Departmental research programs include pulsed power techniques, optical and digital signal/image processing, optical computing, VLSI design, control systems, neural networks, plasma theory and applications, thin film deposition, power semiconductor devices and electronics, electric propulsion, renewable energy systems and systems theory. Texas Tech University is ■ comprehensive state-supported university (including a Law School and Medical School) with approximately 25,000 students. The College of Engineering has 9 departments, a current enrollment of approximately 2300 undergraduate students, 500 graduate students, and 100 faculty. Applicants must have a doctoral degree in electrical engineering or a related field, an outstanding record of accomplishments, familiarity with national trends in electrical engineering education, plus demonstrated leadership and managerial skills. The successful candidate should be able to be appointed at the rank of professor and either be registered or be capable of being registered as a professional engineer in Texas. The University is located in Lubbock, a city of just under 200,000 population. Lubbock is the agricultural, business and medical center for ■ major portion of northwest Texas and eastern New Mexico. Lubbock has been nationally recognized for its friendly people, temperate climate, and quality of life. Applications will be reviewed beginning June 1, 1995, and the search will continue until the position is filled, with the position becoming available January 1, 1996. Application materials, including ■ letter expressing interest in the position and describing the applicant's managerial experience, a detailed resume and a list of at least 5 professional references should be sent to: Professor Warren K. Wray, Chairman, EE Chairperson Search Committee, Department of Electrical Engineering, Texas Tech University, Box 43012, Lubbock, TX 79409-3102, phone: 806/742-3523. Texas Tech University is an Equal Opportunity/Affirmative Action Employer.

The Hong Kong Polytechnic University (formerly Hong Kong Polytechnic) invites applications for the following post: Department of Electrical Engineering - Professor/Associate Professor/Assistant Professor. Applicants in the areas of Power Electronics and Fibre Optics are particularly sought. Other areas of interest include Robotics and Control, Electrical Energy Utilization and High Voltage. The appointees will be required to (a) teach at both undergraduate and postgraduate levels; (b) undertake research and supervise research students; (c) participate in activities on the development of courses, syllabuses and laboratories; and (d) engage in consultancy, scholarly activities or services to the community. Applicants should have (a) a PhD degree; (b) ■ good research track record; (c) appropriate teaching experience; (d) contributions in professional and community services; and (e) relevant industrial experience. For appointment at Associate Professor level, research leadership ability is expected, and ■ distinguished record of research and publication is required for Professorship. Salary and Conditions of Service - Professor: HK$669,360 - HK$889,260 per annum; Associate Professor: HK$641,580 - HK$861,900 per annum; Assistant Professor: HK$412,980 - HK$468,480 per annum /BAR/ HK$496,320 - HK$689,880 per annum. (US$1 = HK$7.7 as of 10 March 1995) Initial appointments are normally made on a fixed term gratuity-bearing contract of two years, at the end of which re-engagement is subject to mutual agreement. Other benefits include leave, medical and dental schemes, children's education allowance, and subsidized housing where applicable. Application: Application including curriculum vitae and names of three referees should be sent to the Personnel Office, Room AG 426, Chung Sze Yuen Building, The Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong before June 15, 1995. [Fax (852) 2764 3374, E-mail GSSTAFF@HKPCC.HKP.HK].

The Swiss Federal Institute of Technology Zurich (ETHZ) invites applications for ■ Chair in Electromagnetic Fields. Teaching and research focus on electrodynamics, with particular emphasis on the numerical simulation of electromagnetic fields. Possible ranges of application are electromagnetic compatibility and antenna design. The new professor will teach field theory to the students in electrical engineering. Candidates should hold ■ university degree and have a distinguished record of qualified research and industrial experience in the subject areas. The new professor must be a talented teacher and willing to collaborate with colleagues both within and outside ETHZ. Please submit your application, together with ■ curriculum vitae, a list of publications and ■ brief description of your research and teaching interests, to the President of ETH Zurich, Prof. Dr. J. Nüesch, ETH Zentrum, CH-8092 Zurich, no later than June 15, 1995. The ETHZ specifically encourages female candidates to apply with ■ view towards increasing the proportion of female professors.

Clemson University: The Department of Electrical and Computer Engineering anticipates having tenure track Assistant Professor and Research Associate/Assistant Professor (non-tenure track) positions available in the Fall semester of 1995. Individuals whose interests and experience match existing research strengths in Integrated Manufacturing (VLSI and Mechatronics) will be given preference. The VLSI group is active in Metal Organic Chemical Vapor Deposition, reliability and design. The Mechatronics group is active in control, design and experimentation for electromechanic systems. Other research areas include Communications, Energy systems and Specialized Computer systems. Candidates should hold a Ph.D. degree in Electrical or Computer Engineering and have ■ strong interest in contributing to a research program. Teaching of core courses at both the graduate and undergraduate levels is expected. Qualified applicants should send ■ curriculum vitae and the names of at least three references to Chair, Search and Screening Committee, Department of Electrical and Computer Engineering, Clemson University, Box 340915, Clemson, South Carolina 29634-0915. Consideration of candidates will begin May 1, 1995 and will continue until positions are filled. Clemson University is an Equal Opportunity/Affirmative Action Employer.

UC Berkeley, Computer Science Department Associate Specialist: Duties of Position: Specification, design, implementation and testing of systems for speech recognition and processing of auditory information. Specific duties include the design, implementation, and testing of very

large scale analog integrated circuits; design and testing of circuit boards, development of custom software for processing of auditory data; and integration of custom hardware and software. Participation in research project planning. Co-authorizing funding proposals and research papers. Qualifications: Ph.D. degree in EECS and expertise in the design of subthreshold analog MOS circuits. Experience with speech recognition hardware and software systems. Experience in the development and maintenance of CAD software for analog VLSI chip design. Also knowledge and experience with auditory and visual processing. Salary Range: $51,204 - $79,164. Please send applications/resumes to: Terry Lessard-Smith, Computer Science Division, UC Berkeley, 643 Soda Hall, Berkeley, CA 94720-1776. Deadline for the applications is June 30, 1995. The University of California is an Affirmative Action/Equal Opportunity Employer.

Institut Eurécom (France): The Department of Multimedia Communications is seeking applications for an Associate Professor or Full Professor tenure position in Software Engineering for Multimedia Applications and Services. Eurécom is a joint venture between Ecole Nationale Supérieure de Télécommunications (Paris) and Ecole Polytechnique Federale de Lausanne (Switzerland) for delivering a graduate curriculum in Communications Systems and pursuing research in related domains with emphasis on system development conceptualization. It is located in the Telecom valley at Sophia Antipolis (French Riviera). Teaching is delivered in French and English. Fluent knowledge of English is mandatory. Knowledge of French could be acquired in the long term. The faculty staff is widely international and consists of 9 professors with assistants. Applicants must have earned ■ doctorate for five years at least and have ■ significant list of publications in top rank level journals with expertise of state of the art tools and methods. Duties of the successful candidate will include graduate teaching, Ph.D. supervision, development of a research program and participation in on-going research in ■ multidisciplinary environment working on Multimedia applications. Strong experience is required in software engineering, operating systems, software and system modelling, object oriented approaches, protocol development, man machine interfaces, information retrieval and system integration. Practice of management of research projects is desirable. Applications will be accepted until the position is filled. Salary will depend on experience and qualifications. Resumes, lists of publications, research plans and the names of five references should be sent to Professor Chris J. Wellekens, Head of the Department Multimedia Communications, Eurécom, 2229 route des Crêtes, BP 193, F-06904 Sophia Antipolis, France.

The Department of Electrical and Computer Engineering (EECE) at the University of New Mexico invites applications for a tenure-track faculty position at the rank of assistant professor, in the area of digital signal processing with an emphasis on speech processing. Minimum requirements: Ph.D. in electrical/computer engineering in the area of digital signal processing, with an emphasis on speech processing. Desired qualifications: Preference will be given to those individuals with ■ strong background in speech processing, industrial experience pertaining to electrical/computer engineering and manufacturing, and experience in outreach activities related to science and engineering education. The EECE Department has approximately 447 undergraduate and 209 graduate students, respectively. Its research expenditures for the 1993-94 fiscal year were about $8.2M. Resume and a list of three references must be received by mail, by July 31, 1995. Send to: Prof. Neeraj Magotra, Search Committee Chair, Electrical and Computer Engineering Department, The University of New Mexico, Albuquerque, NM 87131. The University of New Mexico is an Equal Opportunity and Affirmative Action Employer.

University of Virginia Department of Electrical Engineering invites applicants for two tenure-track positions to begin September 1, 1995. One is in the area of communications and signal processing, and the other is in the area of computer engineering. Applicants for the former position are sought whose interests complement existing strengths in statistical signal processing, digital communications, spread spectrum transmission, and optical communications, and who are able to teach courses in these and related areas. Applicants are sought for the latter position whose interests lie in digital and analog testing, and mixed analog and digital IC design; and complement existing strengths in integrated circuits and systems, test technology, design automation, and fault tolerant computing. Applicants must be able to teach courses in these and related areas. Candidates are required to have an earned doctorate in electrical engineering, ■ strong research record, ability to develop ■ funded research program, and strong commitment to teaching at the graduate and undergraduate levels. Established research programs exist in the Department in the areas of communications and signal processing, computer engineering, solid state electronic and photonic devices, and robotics and machine vision. Our program supports approximately 300 undergraduate students and 130 (65 Ph.D.) graduate students with 20 tenured/tenure track faculty, and three research faculty along with five research scientists. Interested candidates must send a complete resume, indicating citizenship and/or visa status, together with names and addresses of at least four references to Dr. Robert J. Mattauch, Chairman, Department of Electrical Engineering, Thornton Hall, University of Virginia, Charlottesville, VA 22903-2442. This search will continue until the positions are filled. The University of Virginia is an Equal Opportunity/Affirmative Action Employer.

Massachusetts Institute of Technology: The Department of Mechanical Engineering invites applications for an Assistant/Associate tenure track position in Information Science and Technology. The candidate's areas of interest should complement and enhance current research activities in the department in: instrumentation physics; nano-technology; product/system design including database design and networking; information theory, system identification and control systems; intelligent systems and machine learning; bioengineering and man-machine systems; manufacturing and applied mechanics. A Ph.D. in the field of Science or Engineering or equivalent with experience in engineering systems and information science and technology is required as well as a demonstrated ability to carry out innovative research and to conduct outstanding teaching. A strong background in multi-disciplinary engineering systems is highly desirable. Applicants should submit ■ curriculum vitae (with citizenship and/or visa status); a publication list; names, addresses and phone numbers of at least four references; and a one-page professional statement describing their goals and aspirations at MIT. Applications should be sent to: Information Science and Technology Search Chair, Massachusetts Institute of Technology, Department of Mechanical Engineering, Room 3-173, 77 Massachusetts Avenue, Cambridge, MA 02139-4307. MIT is an Equal Opportunity/Affirmative Action Employer. Women and members of minority groups are strongly encouraged to apply.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

The Hong Kong University of Science and Technology invites applications/nominations for the position of Professor and Head of the Electrical and Electronic Engineering Department. Applicants should have appropriate academic and/or professional qualifications together with successful, relevant experience in universities, research laboratories and/or industry. The successful candidate will also be required to demonstrate leadership qualities necessary to lead and manage the department in its diverse academic and administrative functions and to interact effectively with industry and commerce. To receive full consideration, application should be received before June 15, 1995. The search will continue until ■ suitable appointment is made. Applications/nominations together with a curriculum vitae and the names and addresses of at least 3 referees should be sent to: Professor Ming Liou, Chair of the Search Committee, School of Engineering, The Hong Kong University of Science and Technology, Clear Water Bay, Kowloon, Hong Kong. Email: PCCONWAY@usthk.ust.hk.

Department of Physics, National University of Ireland, University College Cork, Ireland: Applications are invited for the following full-time positions in the Physics Department at University College Cork, Ireland, tenable from 1 Sept 1995. (1) College Lectureship in Physics (Permanent post) - Must conduct original research, teach and examine undergraduate and postgraduate courses, participate in departmental administration and development. Requires PhD and distinguished record in research and teaching. Tenure decision follows two-year probationary period. Equivalent to US Assistant Professorship. Salary range: IR£16,120-33,392 (IR£1 = $1.60 approx). (2) Visiting Lectureship in Physics (1 or 2 year contract) similar duties and qualifications to permanent College Lectureship, salary IR£25,000, with research interests relevant to an existing research group in the department (optoelectronics, laser spectroscopy, solid state, relativity, atomic and nuclear physics). (3) EMC Boole Research Fellowship in Physics of Data Storage - Prestigious senior research fellowship in an area relevant to data storage, with special consideration given to expertise in optoelectronics, microstructural physics, ULSI, design and testability of complex systems. Sponsored by EMC Corporation, with whom the holder will interact. PhD and distinguished research required. 2 year contract, renewable. Applicants for (1) should obtain application forms from the Academic Appointments Office, University College, Cork, Ireland, Tel (+353-21) 902 364, Fax 276 995. Applicants for (2) and (3) should send a resume, together with the names of three referees to Professor John G. McInerney, Head of Department of Physics, University College, Cork, Ireland, Tel (+353-21) 902 327, Fax (+353-21) 276 949. Internet: mcinerney@bureau.ucc.ie. All applications must be received by 30 June 1995.

Post-doc, engineer and graduate assistantship positions available in MEMS/Biomed. MEMS experience required (linear actuators exp. desirable) for post-doc. IC or MEMS experience required for engineer with BS in EE, ME or related field. Send CV and the names of 3 references to Dr. Dave Beebe, Dept. of Biomedical Eng., Louisiana Tech University, 711 S. Vienna St., Ruston, LA 71270. E-mail: bme@engr.latech.edu Applications reviewed starting June 1, 1995. Louisiana Tech is an equal opportunity university. Women and minorities are encouraged to apply.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Queen's University, Department of Electrical and Computer Engineering: Research Scientist. This is an immediate requirement for a one-year contract position, with the possibility of extension. Responsibilities: participate in university-industry collaborative research project in automatic detection and recognition of objects from airborne synthetic aperture radar (SAR) imagery and in development of techniques for optimal fusion of SAR, radar, and infrared imaging sensor data. Requirements: PhD and outstanding research record in the area of image processing. Experience with SAR image processing an asset. Salary dependent upon qualifications. Send a detailed CV and names of three references by July 1, 1995 to Prof. Steven D. Blostein, Dept. Electrical and Computer Engineering, Queen's University, Kingston, Ontario, K7L 3N6, Fax 613-545-6615. In accordance with Canadian immigration requirements, priority will be given to Canadian citizens and permanent residents. Queen's University is committed to employment equity.

The University of Toronto, Department of Mechanical Engineering, invites applications for an academic tenure stream position at the rank of Assistant Professor. The successful applicant will be expected to develop an independent research program in the area of Design and will be expected to make a major contribution to the Undergraduate and Graduate Design Programs. Applicants must have a doctoral degree, an outstanding academic record, excellent communications skills and effective teaching ability and should be prepared to obtain registration with the Professional Engineers of Ontario (PEO). Start date is July 1st, 1995 or as soon as possible thereafter. Applicants should include in their responses a detailed curriculum vitae, a clear statement of their specific teaching and research interests, and the names of three persons able to provide references in support of their application. Letters of application should be addressed to: Professor I.G. Currie, Chair, Department of Mechanical Engineering, University of Toronto, 5 King's College Road, Toronto, Ontario M5S 1A4. The closing date for applications to be received is June 15th, 1995. In accordance with Canadian Immigration requirements, priority will be given to applications from Canadian citizens and permanent residents of Canada. The University of Toronto is committed to employment equity and encourages applications from women, visible minorities, aboriginal people and physically challenged persons.

Turabo University, School of Engineering has faculty openings in the area of Electrical Engineering beginning August 1995 and January 1996. A Ph.D. in E.E. or a closely related area is required. The School of Engineering was founded in 1990 and currently offers a quality education to nearly 250 undergraduate students in M.E. and Mfg.E. disciplines. The School's Electrical Engineering program will begin accepting its own students in August 1995. The School enjoys substantial support from the U.S. DOE's Science & Technology Alliance which includes Sandia, Los Alamos, and Oak Ridge National Laboratories. Significant funds are available for the planning and development of research quality laboratories. Faculty members are expected to teach in English and develop the curriculum during a ten month academic year. The Alliance provides summer research opportunities at the national labs. The University is located in the scenic hills of Gurabo, Puerto Rico, minutes from San Juan and the Caribbean coast. Candidates need legal permission to work in the United States and should submit a letter of interest and a resume to: Dr. Roberto Loran, School of Engineering, Turabo University, Box 3030, Gurabo, Puerto Rico 00778. Turabo University is an equal opportunity employer (M/F/D/V).

The Swiss Federal Institute of Technology Zurich (ETHZ) invites applications for the position of an Assistant Professor of Nonlinear Systems. Teaching and research will focus on the analysis and control of nonlinear systems. Candidates should have a strong mathematical background and a solid research record in the subject area. The post of an assistant professor has been established to promote the career of young scientists. It is available for three years in the first instance, with the possibility of a renewal for another three years. Please submit your application, together with a curriculum vitae and a list of publications, to the President of ETH Zurich, Prof. Dr. J. Nüesch, ETH Zentrum, CH-8092 Zurich, no later than June 30, 1995. The ETHZ specifically encourages female candidates to apply with a view towards increasing the proportion of female professors.

Colorado School of Mines Department of Engineering - Engineer: The CSM Department of Engineering is seeking an individual to provide research engineer support with a strong background in the design and implementation of experimental instrumentation and automatic control. A major portion of this position requires original design and construction of instrumentation hardware and software associated with graduate research in mechanical, electromechanical, civil and electronic systems. The successful candidate must be able to interact with graduate students and faculty to determine the functional specifications of such devices and help oversee the research laboratory work of graduate students. The person will be expected to design, develop, and implement a graduate level laboratory course in instrumentation and measurement. The successful candidate is expected to have at least 5 years of experience in the design and construction of electronic circuits, software development for on-line data acquisition, and both low and high level programming skills for establishing communication between computers and instrumentation. A minimum of a B.S. degree in mechanical or electrical engineering is required. A competitive salary and benefit package will be offered the successful candidate. The deadline for application is May 31, 1995. Send letter of application and resume to: Colorado School of Mines, Research Engineer Search #95-011510, 1500 Illinois Street, Golden, CO 80401. CSM is an AA/EEO employer. Women and minorities are encouraged to apply.

Postdoctoral Research Position: The Dept. of Electrical Engineering at the University of Kentucky is seeking to fill a postdoctoral position to further the development of full-wave analyses of microwave circuits and antennas, electronic and microwave packages, and bi-anisotropic materials. Prospective candidates should hold a Ph.D. in Engineering or Physics with strong experience in computational methods. Please send resume and references to Dr. Stephen Gedney, 453 Anderson Hall, Lexington, KY 40506 (email: gedney@engr.uky.edu.).

The Department of Electrical and Computer Engineering at Concordia University invites applications for a tenure-track position in Computer Engineering at the Assistant Professor level. This position is in the Protocol Engineering area with emphasis on Telecommunications Networking/Software and Formal Methods for Protocol Design and Validation. Applicants specializing in the general area of Computer Engineering may also be considered. Applicants must have a Ph.D. in Electrical/Computer Engineering or Computer Science and a strong commitment to excellence in research and teaching at the undergraduate and graduate levels. Knowledge of French is an asset. The candidates are expected to possess qualifications essential to register as a Professional Engineer. The Department offers Bachelor's programs in Electrical and Computer Engineering and Master's and Doctoral programs in Electrical Engineering. The department currently has 27 full-time faculty members. Faculty research interests in Computer Engineering cover VLSI Systems Design; High Performance Architecture and Computing; Parallel CAD; Communication Network/Systems and Performance Evaluation; Robotics and Signal Processing Algorithms. In accordance with Canadian Immigration requirements, priority will be given to citizens and permanent residents of Canada. Concordia University is committed to employment equity and encourages applications from women, aboriginal people, visible minorities and disabled persons. All things begin equal, women candidates shall be given priority. Applications will be accepted until the position is filled. Applicants should send a resume and names of at least three references to: Dr. G. Joos, Acting Chair, Department of Electrical and Computer Engineering, Concordia University, 1455 de Maisonneuve Blvd., West, Montreal, Quebec, H3G 1M8, Canada. Phone: (514) 848-3080, Fax: (514) 848-2802, Email: geza@ece.concordia.ca

Director, Remote Sensing and Image Processing Laboratory, College of Engineering, Louisiana State University: Applications and nominations are sought for the position of Director of the Remote Sensing and Image Processing (RSIP) Laboratory in the College of Engineering. RSIP is a modern interdisciplinary laboratory which focuses on research related to Remote Sensing, Image Processing, Geographic Information Systems (GIS), Global Positioning Systems (GPS), Intelligent Transportation Systems (ITS), Civil Infrastructure Systems, Communications, Technology Integration, Simulation and Modelling, and software engineering. The Laboratory has funded research projects with several government agencies including the U.S. and Louisiana Departments of Transportation, Louisiana Department of Environmental Quality, FHWA, National Academy of Sciences, USAE Waterways Experiment Station, and National Aeronautics and Space Administration. Candidates should have the academic qualifications (Ph.D. or equivalent degree) necessary to hold a senior appointment in one of the departments of the College, have a demonstrated track record of success in external funding and scholarly activities and evidence of ability to work with academic, government, and industrial groups. Salary will be commensurate with experience and accomplishments. Applications to: Edward McLaughlin, Dean, College of Engineering, Louisiana State University, Baton Rouge, LA 70803-6401 will be received until June 30, 1995, or until a suitable candidate is found, and should include a current resume and names, addresses, and phone numbers of three references. Appointment as early as Fall, 1995, will be considered. LSU is an Equal Opportunity/Affirmative Action Employer.

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3	16	29	42	55	[illegible]	81	94	107	120	133	146	159	172	185	198	211	224	237	250	263	276	289	302
4	17	30	43	56	69	82	95	108	121	134	147	160	173	186	199	212	225	238	251	264	277	290	303
5	18	31	44	57	70	83	96	109	122	135	148	161	174	187	200	213	226	239	252	265	278	291	304
[illegible]	19	32	45	58	71	84	97	110	123	136	149	162	175	188	201	214	227	240	253	266	279	292	305
7	20	33	46	59	72	85	[illegible]	111	124	137	150	163	176	189	202	215	228	241	254	267	280	293	306
8	21	34	47	60	73	86	99	112	125	138	151	164	177	190	203	216	229	242	255	268	281	294	307
[illegible]	22	35	48	61	74	87	100	113	126	139	152	165	178	191	204	217	230	243	256	269	282	295	308
10	23	36	49	62	75	[illegible]	101	114	127	140	153	166	179	192	205	218	231	244	257	270	283	296	309
11	24	37	50	63	76	89	102	115	128	141	154	167	180	193	206	219	232	245	258	271	284	297	310
12	25	38	51	64	77	90	103	116	129	142	155	168	181	194	207	220	233	246	259	272	285	298	311
13	26	39	52	65	78	91	104	117	130	143	156	169	182	195	208	221	234	247	260	273	286	299	312

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come. Candidates should have received a doctoral degree by the time the appointment at MIT starts, and should have an active interest in both teaching and research at the university level. The Department of Civil and Environmental Engineering is committed to seeking qualified minority and women faculty candidates. We strongly urge them to apply for this position. Applicants should send a c.v., undergraduate and graduate transcripts, a description of teaching and research interests and a list of references to: Prof. Robert Logcher, Chairman, Faculty Search Committee, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room 1-253, Cambridge, MA 02139.

The University of Toledo, College of Engineering - Chairperson, Department of Electrical Engineering and Computer Science: Applications and nominations are invited for the position of Chair of the Department of Electrical Engineering and Computer Science. Applicants should have an earned doctorate in electrical engineering, computer engineering, computer science or related discipline; ■ commitment to excellence in engineering education; an outstanding research and scholarship record; and strong leadership abilities. The successful candidate will also assume ■ tenured associate professor or professor faculty position. The Department of Electrical Engineering and Computer Science has 29 faculty and offers degrees in both Electrical Engineering and Computer Science and Engineering. Both programs are ABET accredited and the CSE program is also CSAB accredited. The combined full-time and part-time undergraduate enrollment in the department is 500 while the total graduate enrollment is 120. The Department of Electrical Engineering and Computer Science is one of six departments in the College of Engineering which has a combined undergraduate and graduate enrollment in excess of 2,300 students. The University is a state supported university enrolling approximately 24,000 students. The campus, located approximately five miles from the downtown area, is very attractive and is adjacent to ■ fine residential section of Toledo. The University of Toledo is committed to faculty diversity and particularly encourages minorities and

Cardinal Station, Washington, D.C. 20064. E-mail contact: winters@pluto.ee.cua.edu. CUA is an equal opportunity/affirmative action employer.

Government/Industry Positions Open

Electrical Engineer for business in NE Ohio. To design PC card drive for PCMCIA type I, type II, type III for desktop computers and upgrade Solid-State Drive for PCMCIA cards. This includes designing PC card drive hardware and software, including interface between ISA bus and PCMCIA sockets, drivers capable of performing plug and play, linking Microsoft flash file system auto booting BIOS; improving the performance of Solid-State Drive for Flash card, static RAM card, OTP card for PCMCIA. Improvements include: hardware, software drive capable of faster speed and user-friendly. Must have B.S. in Computer Science or Electrical Engineering. Academic program must have included one course each in the following areas: Object oriented design (C++, Visual Basic), Advanced Computer System (ISA interface design), Solid-State drive (for Flash card, Static card and OTP card); and PCMCIA. Must have 6 mos in job described or 6 mos exp as electrical engineer. Exp must have included hardware and software in the area of Solid-State drives. 40 hrs/wk, 8:00am-5:00pm, $33,725/yr. Must have proof of legal authority to work indefinitely in U.S. Send resume, course transcript, and cover sheet in duplicate to T. Do, JO# 00850, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Senior Electrical Design Engineer: Engineering company in the Chicago area is seeking a Senior Electrical Design Engineer to design electronic energy saving equipment and automotive electronic products. A strong background in analog design and power electronics is required. Ability to design magnetics is desired. Responsibilities include project management, new product design and manufacturing liaison. Teamwork skills are necessary. International travel required. Flexible hours. Compensation dependent on experience; includes stock and

D EMPLOYMENT TUNITIES

nd resume to ArdryTech LLC, Dr., Waukegan, Illinois 60087.

sign Engineer Wanted: Must rm exp. with PE or EIT. Open- g's/Mgr's. Mail resume to: J.E. ociates, P.O. Box 30926, Tuc- 26. (520)327-7999. Fees Paid.

arch: The Optical Communi- nt has an immediate opening r research position in Optical rrent emphasis is on develop- or planning the introduction of es and architectures in the telecommunications network. didate must have a Ph.D. in a strong background in some ne following areas: network ing/optimization, software tool ect-oriented modeling, net- nd performance analysis, and ns economics. Interested s are requested to send a let- resume, and letters of recom- search Director Erik Nilsson, REF-P360, Tele Danmark Research, Lyngsø Allé 2, 2970 Hørsholm, Denmark.

Electrical Supervisor: Under the direction of the Engineering/Maintenance Manager, the Electrical Supervisor supervises the Electrical Engineers and Electricians in the Hot Mill Department. The Electrical Supervisor is accountable for: interviewing, task assignment, supervision and evaluation of each subordinate under his direction. Additionally, the Electrical Supervisor is directly responsible for the following: making purchase inquiries and purchasing electrical equipment and supplies for the Hot Mill Department; supporting/suggesting new applications and manning machine interfaces using automation technologies, including but not limited to Wonderware, Factory Link, Simovis, VAX; maintaining/repairing AC and DC drives, Cycloconverters, Simoverts, SimoRegs; supporting operators in the operation procedures of ■ CSP Rolling Mill (use and operation of tunnel furnace, mill stands, and coiler); designing and implementing of requested changes in the Level 1 and Level 2 systems of the CSP Rolling Mill; maintaining/repairing Isotope Measuring System-Radiation Thickness Gauge, Width Gauge, and Laser Flatness Control System; maintaining/repairing/redesigning Machinefabrik Hercules Controls Co., Roll Grinders, Kranco, DeShazo and Harnischfeger P & H Cranes, D.C. Traction Locomotives and remote control systems for each; tuning RF transmitters and receivers; maintaining the Jackson Tamper; inspecting power distribution; monitoring ground faults for 4160 breakers; troubleshooting IBM systems, AS400 Systems; providing electrical consultation to other Nucor facilities as required; supporting other personnel with electrical/electronic problems arising in the steel mill. B.S. or equivalent in electrical engineering required. Five years experience as Electrical Engineering Supervisor required. Qualified candidates should have the following special requirements: Ability to manage/support VAX Cluster, VAX System, and have familiarity in Fortran, DecForms, DecWindows application programming; ability to engineer/design and install Ethernet Networks using bridges, gateways, and various adapters and pathworks, PC support and Lan-

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CLASSIFIED EM OPPORTU

Queen's University, Depa and Computer Engineer tist. This is an immediate year contract position, v extension. Responsibilities sity-industry collaborative automatic detection and from airborne synthetic imagery and in developm optimal fusion of SAR, rad ing sensor data. Require standing research record processing. Experience cessing an asset. Salary fications. Send a detaile three references by July 1 D. Blostein, Dept. Electric neering, Queen's Univers K7L 3N6, Fax 613-545- with Canadian immigratio ity will be given to Canadi nent residents. Queen's to employment equity.

The University of Toror Mechanical Engineerin for an academic tenure rank of Assistant Professor. The successful applicant will be expected to develop an independent research program in the area of Design and will be expected to make a major contribution to the Undergraduate and Graduate Design Programs. Applicants must have a doctoral degree, an outstanding academic record, excellent communications skills and effective teaching ability and should be prepared to obtain registration with the Professional Engineers of Ontario (PEO). Start date is July 1st, 1995 or as soon as possible thereafter. Applicants should include in their responses a detailed curriculum vitae, a clear statement of their specific teaching and research interests, and the names of three persons able to provide references in support of their application. Letters of application should be addressed to: Professor I.G. Currie, Chair, Department of Mechanical Engineering, University of Toronto, 5 King's College Road, Toronto, Ontario M5S 1A4. The closing date for applications to be received is June 15th, 1995. In accordance with Canadian Immigration requirements, priority will be given to applications from Canadian citizens and permanent residents of Canada. The University of Toronto is committed to employment equity and encourages applications from women, visible minorities, aboriginal people and physically challenged persons.

Turabo University, School of Engineering has faculty openings in the area of Electrical Engineering beginning August 1995 and January 1996. A Ph.D. in E.E. or a closely related area is required. The School of Engineering was founded in 1990 and currently offers a quality education to nearly 250 undergraduate students in M.E. and Mfg.E. disciplines. The School's Electrical Engineering program will begin accepting its own students in August 1995. The School enjoys substantial support from the U.S. DOE's Science & Technology Alliance which includes Sandia, Los Alamos, and Oak Ridge National Laboratories. Significant funds are available for the planning and development of research quality laboratories. Faculty members are expected to teach in English and develop the curriculum during a ten month academic year. The Alliance provides summer research opportunities at the national labs. The University is located in the scenic hills of Gurabo,

neering - Engineer: The CSM Department of Engineering is seeking an individual to provide research engineer support with a strong background in the design and implementation of experimental instrumentation and automatic control. A major portion of this position requires original design and construction of instrumentation hardware and software associated with graduate research in mechanical, electromechanical, civil and electronic systems. The successful candidate must be able to interact with graduate students and faculty to determine the functional specifications of such devices and help oversee the research laboratory work of graduate students. The person will be expected to design, develop, and implement a graduate level laboratory course in instrumentation and measurement. The successful candidate is expected to have at least 5 years of experience in the design and construction of electronic circuits, software development for on-line data acquisition, and both low and high level programming skills for establishing communication between computers and instrumentation. A minimum of ■ B.S. degree in mechanical or electrical engineering is required. A competitive salary and benefit package will be offered the successful candidate. The deadline for application is May 31, 1995. Send letter of application and resume to: Colorado School of Mines, Research Engineer Search #95-011510, 1500 Illinois Street, Golden, CO 80401. CSM is an AA/EEO employer. Women and minorities are encouraged to apply.

Postdoctoral Research Position: The Dept. of Electrical Engineering at the University of Kentucky is seeking to fill ■ postdoctoral position to further the development of full-wave analyses of microwave circuits and antennas, electronic and microwave packages, and bi-anisotropic materials. Prospective candidates should hold a Ph.D. in Engineering or Physics with strong experience in computational methods. Please send resume and references to Dr. Stephen Gedney, 453 Anderson Hall, Lexington, KY 40506 (email: gedney@engr.uky.edu.).

The Department of Electrical and Computer Engineering at Concordia University invites

begin equal, women candidates shall be given priority. Applications will be accepted until the position is filled. Applicants should send a resume and names of at least three references to: Dr. G. Joos, Acting Chair, Department of Electrical and Computer Engineering, Concordia University, 1455 de Maisonneuve Blvd., West, Montreal, Quebec, H3G 1M8, Canada. Phone: (514) 848-3080, Fax: (514) 848-2802, Email: geza@ece.concordia.ca

Director, Remote Sensing and Image Processing Laboratory, College of Engineering, Louisiana State University: Applications and nominations are sought for the position of Director of the Remote Sensing and Image Processing (RSIP) Laboratory in the College of Engineering. RSIP is a modern interdisciplinary laboratory which focuses on research related to Remote Sensing, Image Processing, Geographic Information Systems (GIS), Global Positioning Systems (GPS), Intelligent Transportation Systems (ITS), Civil Infrastructure Systems, Communications, Technology Integration, Simulation and Modelling, and software engineering. The Laboratory has funded research projects with several government agencies including the U.S. and Louisiana Departments of Transportation, Louisiana Department of Environmental Quality, FHWA, National Academy of Sciences, USAE Waterways Experiment Station, and National Aeronautics and Space Administration. Candidates should have the academic qualifications (Ph.D. or equivalent degree) necessary to hold a senior appointment in one of the departments of the College, have a demonstrated track record of success in external funding and scholarly activities and evidence of ability to work with academic, government, and industrial groups. Salary will be commensurate with experience and accomplishments. Applications to: Edward McLaughlin, Dean, College of Engineering, Louisiana State University, Baton Rouge, LA 70803-6401 will be received until June 30, 1995, or until a suitable candidate is found, and should include a current resume and names, addresses, and phone numbers of three references. Appointment as early as Fall, 1995, will be considered. LSU is an Equal Opportunity/Affirmative Action Employer.

Faculty Position Announcements - Assistant Professor - Information Technology: The Department of Civil and Environmental Engineering at Massachusetts Institute of Technology is seeking candidates in the field of Applied Information Technology for a tenure track position at the Assistant Professor Level. Candidates should have ■ strong record of research and/or teaching concerned with the application of information technology to large scale civil engineering systems. Examples of relevant topics include (but are not limited to) real-time active building control systems, embedded condition assessment and monitoring systems, and predictive traffic management systems. Focus is on changing the functionality, nature or use of ■ civil engineering product. The successful candidate is expected to have in-depth knowledge in several of the following areas: CAD, object oriented systems, knowledge based systems, database technology, software development methodologies and real-time systems. The Department is involved in a wide range of interdisciplinary research activities at MIT, including the Center for Transportation Studies, the Center for Global Climate Change, the Center for Construction Research and Education, the Center for Educational Computing Initiatives and the Center for Technology, Policy and Industrial Development. Candidates capable of contributing to the excellence of the research and educational programs of these organizations are welcome. Candidates should have received a doctoral degree by the time the appointment at MIT starts, and should have an active interest in both teaching and research at the university level. The Department of Civil and Environmental Engineering is committed to seeking qualified minority and women faculty candidates. We strongly urge them to apply for this position. Applicants should send a c.v., undergraduate and graduate transcripts, a description of teaching and research interests and a list of references to: Prof. Robert Logcher, Chairman, Faculty Search Committee, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Room 1-253, Cambridge, MA 02139.

The University of Toledo, College of Engineering - Chairperson, Department of Electrical Engineering and Computer Science: Applications and nominations are invited for the position of Chair of the Department of Electrical Engineering and Computer Science. Applicants should have an earned doctorate in electrical engineering, computer engineering, computer science or related discipline; a commitment to excellence in engineering education; an outstanding research and scholarship record; and strong leadership abilities. The successful candidate will also assume a tenured associate professor or professor faculty position. The Department of Electrical Engineering and Computer Science has 29 faculty and offers degrees in both Electrical Engineering and Computer Science and Engineering. Both programs are ABET accredited and the CSE program is also CSAB accredited. The combined full-time and part-time undergraduate enrollment in the department is 500 while the total graduate enrollment is 120. The Department of Electrical Engineering and Computer Science is one of six departments in the College of Engineering which has ■ combined undergraduate and graduate enrollment in excess of 2,300 students. The University is ■ state supported university enrolling approximately 24,000 students. The campus, located approximately five miles from the downtown area, is very attractive and is adjacent to a fine residential section of Toledo. The University of Toledo is committed to faculty diversity and particularly encourages minorities and females to apply. Applicants should send a resume, four references, and a letter outlining their qualifications and experience which make them strong candidates for the position. The Search Committee will begin to review applications on July 1, 1995. To insure full consideration, all applications should be received prior to that date. The position will remain open and applications will be reviewed on the 1st of each month until an appointment is made. Send all materials to Professor Phillip R. White, College of Engineering, The University of Toledo, Toledo, OH 43606-3390. Email: pwhite@uoft02.utoledo.edu, Fax: 419-537-2805. The University of Toledo is an Affirmative Action Employer. Women and minorities are encouraged to apply.

Biomedical Engineering, Catholic University of America, Assistant Professor, tenure track, starting Fall semester, '95. Candidates expected to teach undergraduate and graduate courses and to develop a productive research program. Preference is for rehabilitation engineering, although candidates in all areas of biomedical engineering will be considered. Applications will be reviewed starting June 1 and will continue to be evaluated until position filled. Send resume and statement of teaching and research objectives, plus addresses and phone numbers of 3 references to: Search Committee, Biomedical Engineering, The Catholic University of America, Cardinal Station, Washington, D.C. 20064. E-mail contact: winters@pluto.ee.cua.edu. CUA is an equal opportunity/affirmative action employer.

Government/Industry Positions Open

Electrical Engineer for business in NE Ohio. To design PC card drive for PCMCIA type I, type II, type III for desktop computers and upgrade Solid-State Drive for PCMCIA cards. This includes designing PC card drive hardware and software, including interface between ISA bus and PCMCIA sockets, drivers capable of performing plug and play, linking Microsoft flash file system auto booting BIOS; improving the performance of Solid-State Drive for Flash card, static RAM card, OTP card for PCMCIA. Improvements include: hardware, software drive capable of faster speed and user-friendly. Must have B.S. in Computer Science or Electrical Engineering. Academic program must have included one course each in the following areas: Object oriented design (C++, Visual Basic), Advanced Computer System (ISA interface design), Solid-State drive (for Flash card, Static card and OTP card); and PCMCIA. Must have 6 mos in job described or 6 mos exp as electrical engineer. Exp must have included hardware and software in the area of Solid-State drives. 40 hrs/wk, 8:00am-5:00pm, $33,725/yr. Must have proof of legal authority to work indefinitely in U.S. Send resume, course transcript, and cover sheet in duplicate to T. Do, JO# 00850, Ohio Bureau of Employment Services, P.O. Box 1618, Columbus, Ohio 43216.

Senior Electrical Design Engineer: Engineering company in the Chicago area is seeking a Senior Electrical Design Engineer to design electronic energy saving equipment and automotive electronic products. A strong background in analog design and power electronics is required. Ability to design magnetics is desired. Responsibilities include project management, new product design and manufacturing liaison. Teamwork skills are necessary. International travel required. Flexible hours. Compensation dependent on experience; includes stock and profit sharing. Send resume to ArdryTech LLC, 1604 MacArthur Dr., Waukegan, Illinois 60087.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Project Electrical Design Engineer Wanted: Must have consulting firm exp. with PE or EIT. Openings for Project Eng's/Mgr's. Mail resume to: J.E. Connelly, CS Associates, P.O. Box 30926, Tucson, AZ 85751-0926. (520)327-7999. Fees Paid.

Tele Danmark Research: The Optical Communications Department has an immediate opening for a 2- to 3- year research position in Optical Networks. The current emphasis is on developing models/tools for planning the introduction of broadband services and architectures in the access part of the telecommunications network. The selected candidate must have a Ph.D. in a related field and ■ strong background in some combination of the following areas: network architecture planning/optimization, software tool development, object-oriented modeling, network simulation and performance analysis, and telecommunications economics. Interested qualified applicants are requested to send a letter of application, resume, and letters of recommendation to: Research Director Erik Nilsson, REF-P360, Tele Danmark Research, Lyngsø Allé 2, 2970 Hørsholm, Denmark.

Electrical Supervisor: Under the direction of the Engineering/Maintenance Manager, the Electrical Supervisor supervises the Electrical Engineers and Electricians in the Hot Mill Department. The Electrical Supervisor is accountable for: interviewing, task assignment, supervision and evaluation of each subordinate under his direction. Additionally, the Electrical Supervisor is directly responsible for the following: making purchase inquiries and purchasing electrical equipment and supplies for the Hot Mill Department; supporting/suggesting new applications and manning machine interfaces using automation technologies, including but not limited to Wonderware, Factory Link, Simovis, VAX; maintaining/repairing AC and DC drives, Cycloconverters, Simoverts, SimoRegs; supporting operators in the operation procedures of ■ CSP Rolling Mill (use and operation of tunnel furnace, mill stands, and coiler); designing and implementing of requested changes in the Level 1 and Level 2 systems of the CSP Rolling Mill; maintaining/repairing Isotope Measuring System-Radiation Thickness Gauge, Width Gauge, and Laser Flatness Control System; maintaining/repairing/redesigning Machinefabrik Hercules Controls Co., Roll Grinders, Kranco, DeShazo and Harnischfeger P & H Cranes, D.C. Traction Locomotives and remote control systems for each; tuning RF transmitters and receivers; maintaining the Jackson Tamper; inspecting power distribution; monitoring ground faults for 4160 breakers; troubleshooting IBM systems, AS400 Systems; providing electrical consultation to other Nucor facilities as required; supporting other personnel with electrical/electronic problems arising in the steel mill. B.S. or equivalent in electrical engineering required. Five years experience as Electrical Engineering Supervisor required. Qualified candidates should have the following special requirements: Ability to manage/support VAX Cluster, VAX System, and have familiarity in Fortran, DecForms, DecWindows application programming; ability to engineer/design and install Ethernet Networks using bridges, gateways, and various adapters and pathworks, PC support and Lan-

tastic; ability to engineer/design and develop new basic automation applications using STRUC-G and Stage 5 software on Simadyn-D Systems, Siemens S5 PLC and Level I controls; ability to engineer/redesign, maintain, and repair electrical equipment in a CSP Rolling Mill using Oscilloscopes, meggers, Hi-Pots, etc., also using preventative maintenance techniques and data acquisition systems; extensive knowledge of ■ continuous strip process down coiler, including ability to design, purchase, install, commission and maintain ■ down coiler; ability to program the VAX System to modify and add applications and have programming skills in Lantastic and the capability of writing database programs for applications used in administrative uses and Fortran, VAC C, VAX, PLM 86. Forty hours/week. Hours Mon.-Fri. 7:00 a.m. to 5:00 p.m., $579.20/week base. Position in Armorel, Arkansas. To apply: mail resume with copy of advertisement attached to Employment Security Division, P.O. Box 1409, Blytheville, AR 72315. JO#838912. Must have proof of legal authority to work in the United States.

Software Scientists/Engineers: Strong background in optical computing and neural network technology for next generation products. Hardware experience desired along with C/C++ and Windows applications. M.S. or Ph.D. in engineering, physics, or computer science. Resumes to Human Resources, Dept. #P95-SSE, 2330 Faraday Ave., Carlsbad, CA 92008. EOE M/F/D/V.

Power MOSFET Design Engineer, C.P. Clare Corporation. C.P. Clare is ■ leading supplier of solid state relays to the telecommunications industry. Candidate must have ■ strong device physics background and minimum M.S. Physics or Electrical Engineering. Proficiency with process/device computer simulation desirable and knowledge of power/high voltage MOSFET design essential. Familiarity with Cadence layout editor ■ plus. Prior design experience in industry would be ■ definite plus. Salary commensurate with experience. C.P. Clare Corporation offers a full benefits package and is an equal opportunity employer. Please send resume and cover letter with salary requirements to: Manager Human Resources, C.P. Clare Corporation, Solid State Products Division, 8 Corporate Place, 107 Audubon Road, Wakefield, MA 01880. No phone calls please.

Senior Product Development Specialist: Design, implement, test and document administrative software applications, including payroll processing, personnel administration and state and federal reporting for school districts in the State of Washington. Develop application software in the Progress programming language, utilizing structured design methodologies and computer aided software engineering tools. Requirements: Bachelor's Degree in Business/Computer Science. Four years experience as Senior Product Development Specialist or ■■ Management Information Systems Specialist. Three years designing, constructing and maintaining payroll and personnel administrative systems; three years development experience in structured systems analysis and design, including logical and physical data modeling and relational database design; two years implementation experience with the Progress programming language and Xponent CASE tool in a DEC VMS environment; two years experience with Federal and Washington State school district accounting and administrative reporting. Experience may be gained concurrently. References required. Must have legal authority to work in the United States. Job Location: Lynnwood, Washington. Salary: $37,276 per annum, 40+ hours per week, 8-5. By June 1, 1995, send this ad and resume to: Employment Security Department, E&T Div. Job Order No. 477685, Olympia, WA 98507-9046. Cover letter/resume must reflect all requirements.

Electronics Design Engineer (Ref: 29195) to conduct analytical studies on engg proposals to develop designs for electronic components, equipment, sys. & products, applying principles of electronic theory, design & engg; analyze technical features of sensor using modern quality control theory for high quality design; analyze, select & update IC chips for new products; write new types of sensor technical documents; design, build & test prototype electrical & electronic digital & analog circuits; design & develop various types of power supply equipment for new products, control interface equipment, network communication protocol for industrial control sys., micro-controller (Intel & Motorola) sys. using simulator & digital analyzer equipment; design real-time multiple tasks & graphic display s/w using Assembler & C language; design control program using AB PLC-5 lattice language; write user operating manual; design network communication program to monitor production; direct technicians to operate the diagnostics to test products & assist in troubleshooting; use PCAD to design product Print Circuit Boards & ACAD for circuit schematic drawings; Reqs. Master's in Cmpt. Engg, Electrical Engg, Electronic Engg or Electronic Tech. & 2 yrs. exp. in job offered or 2 yrs. related exp. ■■ a Design or Cmpt. Engineer, Design Engineer & Development Group Manager or Cmpt Engineer. The 2 yrs. related exp. must include each of the following: leading or supervising at least 2 engineers or technicians in electronic component design; microcontroller sys. design; controlling electronic circuits; prototyping electronic designs; designing printed circuit boards using PCAD & writing documents describing the electronic design; developing packaging & producing drawings for electronic components using ACAD. Must have 1 grad. level course each involving, in whole or in part, the following areas: Real Time Languages; Assembly Languages & Mini Computer Systems; Switching Circuits; Parallel Processing Hardware; Quality Control; Computer Networking. $3,634/mo. 40 hr/wk., 9-5. Send resume to 7310 Woodward Ave., Rm 415, Detroit, MI 48202 & include Ref #. Employer Paid Ad.

Seeking an E.E. knowledgeable in music-notation and composition for development (from patent specs.) of ■ mechanical music-printing computer apparatus for a possible joint venture. Contact: Joseph P. Acciani, 121 Webster Ave., Seaside Heights, NJ 08751-2331.

Engineer, Electromagnetic: Design & analyze antennas & microwave components/systems. LJR is a dynamic, growing consulting firm whose work varies from antenna design & modeling to satellite systems analysis. Looking for bright, industrious, practical engineers at all experience levels. U.S. Citizenship. Send resume to John Mahon, LJR Inc., 360 N. Sepulveda Blvd., Suite 2030, El Segundo, CA 90245.

USAF/Armstrong Laboratory/Brooks AFB: Immediate postdoctoral position available in theoretical and numerical computations involving nonlinear optics, ultrashort pulse phenomena, laser-matter interactions, and nonlinear partial differential equations. Applicant should have strong background in mathematical methods and a PhD (or near completion) in Applied Mathematics, Physics, Electrical Engineering or a related field. Applications will be considered until the position is filled, however for timely consideration, please respond by June 1, 1995. Applicant must be US citizen. Please send resume and a list of three references to Dr. R. Albanese, AL/OES, 8308 Hawks Road, Brooks AFB, San Antonio, TX 78235.

Software Program Manager: By June 1, 1995, please send resume to: Employment Security Department, E&T Division, Job # 478354-G, P.O. Box 9046, Olympia, WA 98507-9046. Job Order Number must be indicated on your response. Job Description: Designs complex software for micro computers under limited supervision. Coordinates program development, writes functional specifications and standards, and performs functional verification of object oriented data access software. Works with software architects to determine design of product, and with marketing team to determine technical vision of product and to deliver technical product presentations. Utilizes "C" and SQL programming languages and Windows and multitasking/multithreaded operating systems. Requirements: Bachelor's degree or equivalent in Electrical Engineering, Computer Science, Mathematics or Physics; three years of related experience is equivalent to one year of education. 2 years experience in job offered or as ■ Programmer and Software Designer to include one year of work experience in each of the following: design and implementation of database management system software and client-server relational database applications, programming or software design utilizing "C" and SQL languages, designing and implementing software to run on Windows and multitasking/multithreaded operating systems, and object oriented software design. Experience must include 20 course hours in business, marketing, and/or economic analysis or six months work experience in business marketing. Experience may be gained concurrently. Must have legal authority to work in the United States. Job Location: Seattle Area Employer. Salary: $50,000-$54,000 per annum, depending on experience. Compensation package includes bonuses, stock options, and other benefits. 40 hours per week, flex time. EOE

Transmission Plant Engineer A: Work Schedule 8:00 A.M. - 5:00 P.M. 40 hrs/wk. $1087.80 p/wk. Engineer and develop specifications, standards, power/computer hardware requirements and electrical protection systems of facilities lighting systems, electrical controls (for hydraulic and shop floor pneumatic machines in moving assembly lines), and computer numerically controlled machines with data acquisition at Engine/Transmission Plants and at vendor sites, for manufacture of passenger car automatic transmissions. Establish power requirements, electrical safety standards, and specifications for powertrain machining equipment (milling, boring, grinding), assy. systems including (material handling, automated parts washers, heat treat systems) and test facilities. Master, Electrical Engineering. Three years experience in job or Related Occupation of Project Engineer. Three years of Related Occupation experience shall include engineering of heavy industrial computerized machine control systems in manufacturing shop floor, with development of material handling, inventory control, production control and statusing systems, including statistical quality control analysis and advanced electrical protection systems, which may be concurrent with related occupation experience. Employer Paid

Ad. Send resume to Job Service, 7310 Woodward Avenue, Room 415, Detroit, MI 48202, Reference No. 52595.

Applications Sales Engineer - Latin America Region. Work Schedule 8:00 A.M. - 4:30 P.M. 40 hrs/wk. $960.00 P/Wk. Identify and assure product engineering changes to U.S.-manufactured/designed static exciter system, voltage regulator, protective relay and magnetic transformer products, to conform with specification requirements for sale in Mexico and South/Central American countries. Meet and confer with South/Central American government agency officials to explain/define U.S. corporate product/quality standards, identify product specifications/changes made to comply with their local power/safety/labeling standards, and obtain U.S. products registration according to local requirements, assuring local market compliance. Identify requirements and communicate with U.S. production plant for meeting importation requirements. Obtain and complete annual foreign government product and company registrations in Mexico and South/Central American markets, including patent protection for proprietary high tech products. Direct and manage technical engineering, sales and marketing activities in Latin America including training of customers, engineering/technical staffs. Bachelor Degree, Electronics and/or Communications Engineering. Three years experience in job or Related Occupation of Applications Engineer. Three years of Related Occupation experience must include identification and assurance of proper engineering changes and compliance with Mexican and South/Central American market requirements for engineering and exportation of U.S. protective relays and other utility and power generation products to conform with and be admitted to Latin American countries, which may be concurrent with Job or Related Occupation experience. Applicant will be required to undertake 25% overnight travel (equal to approximately 1 trip per month) to Latin America. Employer Paid Ad. Send resume/application to Arkansas Employment Security Department, P.O. Box 1460, Jonesboro, AR 72403, Ref. #838928.

Electronics Engineer: The U.S. Army Research Office is seeking an individual to aid in the administration of an extramural research program in mobile tactical communications networks; sensor, signal, and information processing for target acquisition and image analysis; or the linking of telecommunication or target acquisition algorithms with digital processing hardware. Duties include analyzing and evaluating proposals and reports; maintaining liaison with contractors; analyzing contractor performance; maintaining familiarity with the status of research programs relevant to Army needs; and disseminating program policies, procedures and results to interested parties. This is ■ Federal civilian position at the GS-12 grade level ($45,214 - $57,542 per annum). Applicants must possess a doctoral degree in electronics engineering. To obtain ■ copy of the vacancy announcement and application forms, contact U.S. Army Research Office, Attn: AMXRO-HR, P.O. Box 12211, Research Triangle Park, NC 27709-2211, Ph: 919-549-4212. Closing date is May 26, 1995. An Equal Opportunity Employer. U.S. Citizenship Required.

Medical Ultrasound Engineer: Engineer with 10+ yrs. exp. in design of medical U/S imaging systems. Familiar w/physics of sound propagation & evaluation of acoustic path materials; signal processing path electronics (beamformers, pulsers, etc.); evaluation of U/S image quality & understanding of system/transducer parameters that affect image quality. Expertise in design of analog, RF & digital signal processing components. At least an MSEE with emphasis in signal processing. Job location: Seattle. Send resume/salary requirements to: NeoVision Corp., 319 Nickerson St., Box 142, Seattle, WA 98109.

Electrical Project Engineer needed to coordinate industrial/commercial contracting plans & industrial control panel schematics & life-cycle design. Design electrical systems. Fabricate/test/troubleshoot industrial control panels. Define material requirements based on design, review & analysis. Coordinate engineering estimates. Direct prep. of equipment & materials. Inspect electrical installations & ensure operational standards. Commission & start up projects. Work will incl. oversight responsibility for electricians & technicians, w/significant travel aboard foreign flagged vessels. Requires: B.S. in E.E. w/course work in control systems & electrical materials science; & 6 yrs work exp as electrical engineer on life-cycle design, construction, maintenance, repair, sales & troubleshooting for all types of electrical panels (incl control, alarm, relay, protection, metering, C&I, & programmable logic controllers) incl independent project responsibility for 50 cycle work in high, med & low voltage areas. Exp must incl work on electrical equip made by Siemens, GE, Westinghouse, Stork & Asea-Brown Boveri & 3 yrs of independent project mgmnt w/supervisory responsibility. Salary: $41,600/yr, 40 hrs/wk in Seattle, WA. Send resume by 06/03/95 to: Job Order #472165S, Employment Security Dept., E & T Div., PO Box 9046, Olympia, WA 98507-9046.

Electrical Engineer for Northeast OH steel producer to utilize Autocad, Programmable Logic Controllers (PLC), Modbus Plus Network & CMC drives to research, develop & design electrical components, equipment, systems, instruments, controls & procedures for use in steel production, including burn/cut scrap steel, re-melting & scale pit operation; build & modify electronic option boards for industrial applications; test to conform to functional specifications & requirements. Applicants will qualify with BS in Electrical Engineering (must have completed at least one course each in computer networking, advanced digital design & systems software/operating systems) & 6 months in the job described or 6 months in building & modifying electronic option boards for industrial applications & with burn/cut scrap steel, re-melting & scale pit operations. Experience may have been gained before, during or after degree. Must have completed a year long co-op program in conjunction with Electrical Engineering major. Must provide copies of degree(s), transcript(s) & letter(s) confirming the required experience. 40 hours/week, 8:00am-5:00pm, M-F, $36,000/year. Send 2 resumes, cover letters and copies of degree(s), transcript(s) & letter(s) confirming the required experience (no calls) to T. Do, Job#965, Ohio Bureau of Employment Services, PO Box 1618, Columbus, OH 43216.

Power Design Engineer: Design new power supply for induction heating and DC welding. Start from concept, simulate in SPICE, set up prototype, run test, draw detail schematics and layout PCB for final products. Calibration and troubleshooting on these induction heating high frequency and DC welding power supply (up to 200 kW/30kHz), mainly using power IGBT, SCR and MOSFET.

CLASSIFIED EMPLOYMENT OPPORTUNITIES

Redesign and maintenance AC power supply and Control System for plant and shop. Documentation: circuit schematics, Test instruction, user's manual and product documentation. Req'd: M.S. in Electrical Engineering with 1 year exp. in the job offered or 1 year exp. in a related occupation such ■ Electrical Engineer. Related experience must include Redesigning, testing, troubleshooting, maintaining power system and control system. Academic background must include Courses/Topics each in: Power Transmission and Distribution, Power Electronics, Control System/Theory and Digital Systems Design. 40 hrs/wk. Overtime ■ required. 8:00 am. -5:00 pm. $39,828 per year. Send resumes to: 7310 Woodward Ave., Rm. 415, Detroit, MI 48202. Ref.#31795. "Employer Paid Ad."

Program Management Position/Electronics Engineer/GS-855-13 ($51,688-$67,192). Position may be filled at GS-855-14 level ($61,081-$79,402). The Space Influences on Terrestrial Environment Branch of the Space Environment Laboratory (SEL) of NOAA's Environmental Research Laboratories invites applications for an Electronics Engineer specializing in program management. The position is located in Boulder, Colorado. The incumbent must have experience and demonstrated skills in the management of contracts with the aerospace industry for the procurement of satellite systems and subsystems, in the theory, principles, practices, and techniques of electronic engineering and the design and operation of satellite systems and space flight instrumentation. Knowledge of the design and operation of charged particle detectors and magnetometers, satellite telemetry, data acquisition and processing systems, Federal contracting procedures and policies, and general knowledge of Solar-Terrestrial physics are desirable. The incumbent will be responsible for the technical management and financial oversight of space environment monitoring sensor systems flown on polar and geostationary spacecraft. The incumbent will also be responsible for routine performance assessment of sensors after launch and will serve as the principal interface with SEL's scientific staff on technical aspects of satellite sensor design and operation, both for current and future instruments. Copies of the vacancy announcement listing qualifications, selective and quality ranking factors, and instructions on how and where to apply may be obtained by calling the DOC Jobline at 303-497-6332. For the hearing impaired telephone 303-497-3014. Please reference the vacancy announcement number: MASC/NOAA95-086LR. Completed applications must be received in the Personnel office at U.S. Department of Commerce, NOAA/Personnel Division, MC24, 325 Broadway, Boulder, CO 80303-3328 by the close of business May 31, 1995. The U.S Department of Commerce is an equal opportunity employer. U.S. citizenship is required.

Government/Industry Positions Wanted

MSEE, 2yr exp. DSP/Image/Video Compression. Excellent verbal and written skills. Will relocate. Box 72098, Roselle, IL 60172-0098.

BSEE, dual national, French/American, 18 yrs exp elect utility field incl proj mgmt. seeks position in France with int'l firm. Reply: R. Heldt, 34 rue des Grouettes, 92160 Antony, France. Ph. (33 1)46 60 12 13.

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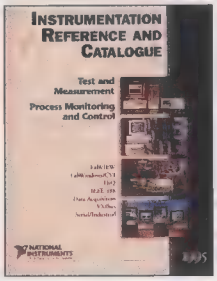
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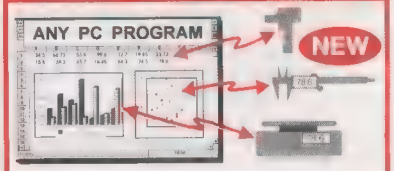
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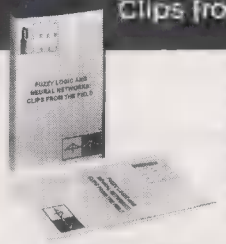
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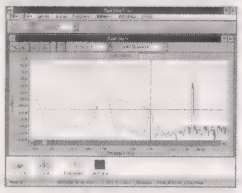
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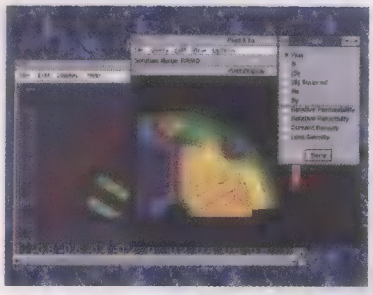
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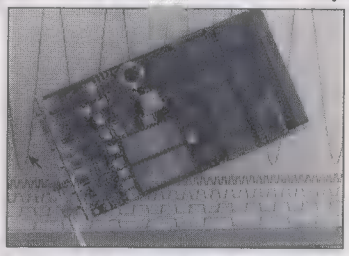
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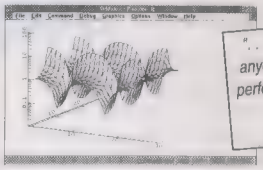
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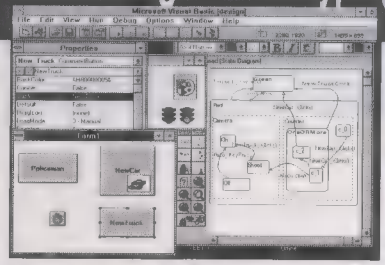
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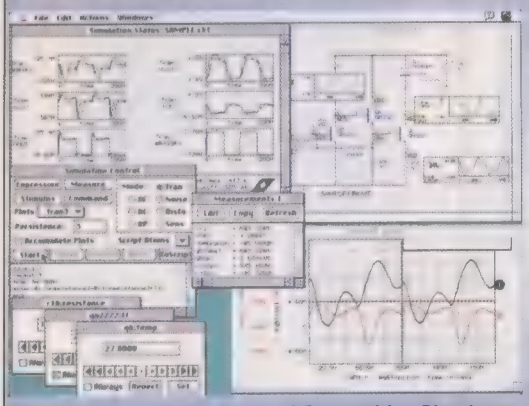


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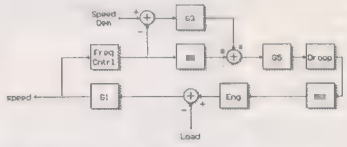
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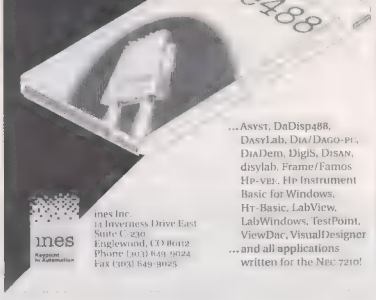
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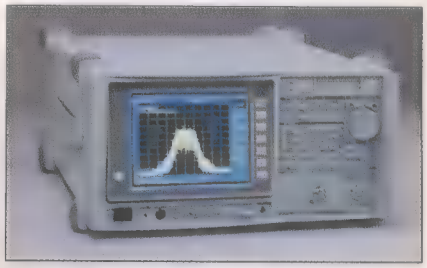
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general interest

On the AIR

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But there is much more to *AIR* than its newest column. *AIR* readers have learned about such matters as motion sickness in amphibians, waist-to-hip ratios in Miss Americas and *Playboy* playmates, the behavior of Japanese tree frogs under microgravity, hypercapnia during retching in dogs, and the collapse of toilets in Glasgow. They have also had the good fortune to learn the views of a Nobel laureate on supermarket etiquette, with emphasis on the propriety of tasting grapes in the store.

For the benefit of those who have never heard of it, *AIR* is subtitled "the journal of inflated research and personalities," which pretty much explains what it is all about. It is produced by the entire former editorial staff (1955–1994) of *The Journal of Irreproducible Results* and published by the MIT Museum in Cambridge, Mass. Its editorial board consists of more than 40 distinguished scientists from around the world, including seven Nobel laureates and a convicted felon.

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new & noteworthy

▪ Silicon Systems, Tustin, Calif., has announced that **1995 catalogs for its communications and storage products** are now being offered. The communications products data book contains more than 700 pages of information on such items as modem support ICs, programmable filters for local-area networks, and pulse-code modulation circuits. More than 1300 pages long, the storage products data book covers such products as read/write amplifiers, head-positioning circuits, and spindle motor controls. Both reference volumes are free of charge. **Circle 105.**

• **A family of 1000–1800-W switching power supplies** for use in computers and communications systems has been announced by Brown Applied Technology Inc., Scarborough, Ont., Canada. The multiple-output units are housed in a low-profile package measuring 80 by 200 by 280 mm. They have efficiencies as high as 83 percent and power-factor correction to 0.99. **Circle 106.**

• Motorola's Customer Specified Integrated Circuits (CSIC) Division, Austin, Texas, has announced **an expandable version of its 68HC05 family of microcontrollers.** Dubbed the 68HC05C0, the new chip addresses up to 64KB of external ROM, which means that it can be offered as an off-the-shelf product with no custom programming and, therefore, instant availability. It operates with both multiplexed and nonmultiplexed buses. The 68HC05C0 sells for $2.20 in high-volume original-equipment manufacturer quantities. **Circle 107.**

▪ Aimed at applications like motor control, computer pointing devices, automotive windshield wiper control, and security systems, the PIC16C65 **E-PROM-based 8-bit microcontroller** from Microchip Technology Inc., Chandler, Ariz., features a fast (5-Mb/s) serial communications port and a high-performance RISC processor core. It is priced at $5.30 in 1000-piece lots and is available from stock. **Circle 108.**

• TerraData, a division of DAS Inc., Orem, Utah, has announced **an extremely high-speed data acquisition board,** the TD-250, for applications like radar that require fast data acquisition in conjunction with real-time hardware averaging. The board's maximum sampling rate is 250 megasamples per second and its maximum analog bandwidth is 125 MHz. Its hardware averaging section can add a new 8-bit digitization of the input signal to a 16-bit sum every 4 ns, in effect increasing the board's resolution to 10 or 11 bits, according to the company. The TD-250 is priced at $7995. **Circle 109.**

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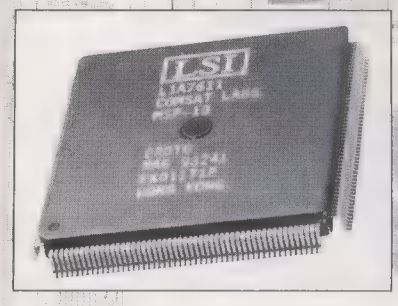
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The use of 'intelligent control'

The demand for highly automated, high-performance systems in such fields as vehicular traffic control, factory automation, and avionics is forcing engineers to turn to machines to perform many tasks traditionally done by human beings. Not surprisingly, those engineers have found it advantageous to study how people traditionally perform such jobs and to incorporate that knowledge in their systems.

Thus, a branch of control theory has been created called "intelligent control" that includes such techniques as fuzzy logic, neural networks, and genetic algorithms. But many in the control field question whether such intelligent systems are being oversold and whether they can or should replace more conventional methodologies.

This article explores these questions. While it comes to no definite conclusions, it does suggest that autonomous systems might best be implemented by a mixture of intelligent and conventional methods.

ISDN—coming into its own?

The jokes about ISDN, the integrated-services digital network, have been numerous. Some said the initials stood for an "interface subscribers don't need," others for "it still does nothing." For a while, the jokes had a point. For a variety of reasons (prohibitive costs, lack of service availability, and so on) this promising technology was not able to offer attractive high-volume products.

That situation is changing. ISDN may now be poised soon to come into its own. This article will review how ISDN has evolved, with an eye on where it is headed.

Tracking weather in space

As engineers have learned over the last four decades, space—just like the earth—has weather of its own. Caused in part by the emissions from solar flares and the earth's own magnetic field, this weather can swamp satellite electronics and disrupt electric power systems and communications. And though it may not be possible to do much about weather in space, engineers and scientists are studying how to predict it and determine what its effects are likely to be.

Jumping to a new technology

No technology company, no matter how successful its current products, can afford to rest on its laurels or ignore industry advances. Proposed a quarter century ago, the technological s-curve is a useful tool for strategists trying to judge the opportune time to move to a new technology. This article describes how engineers can apply the curve to their maximum benefit.

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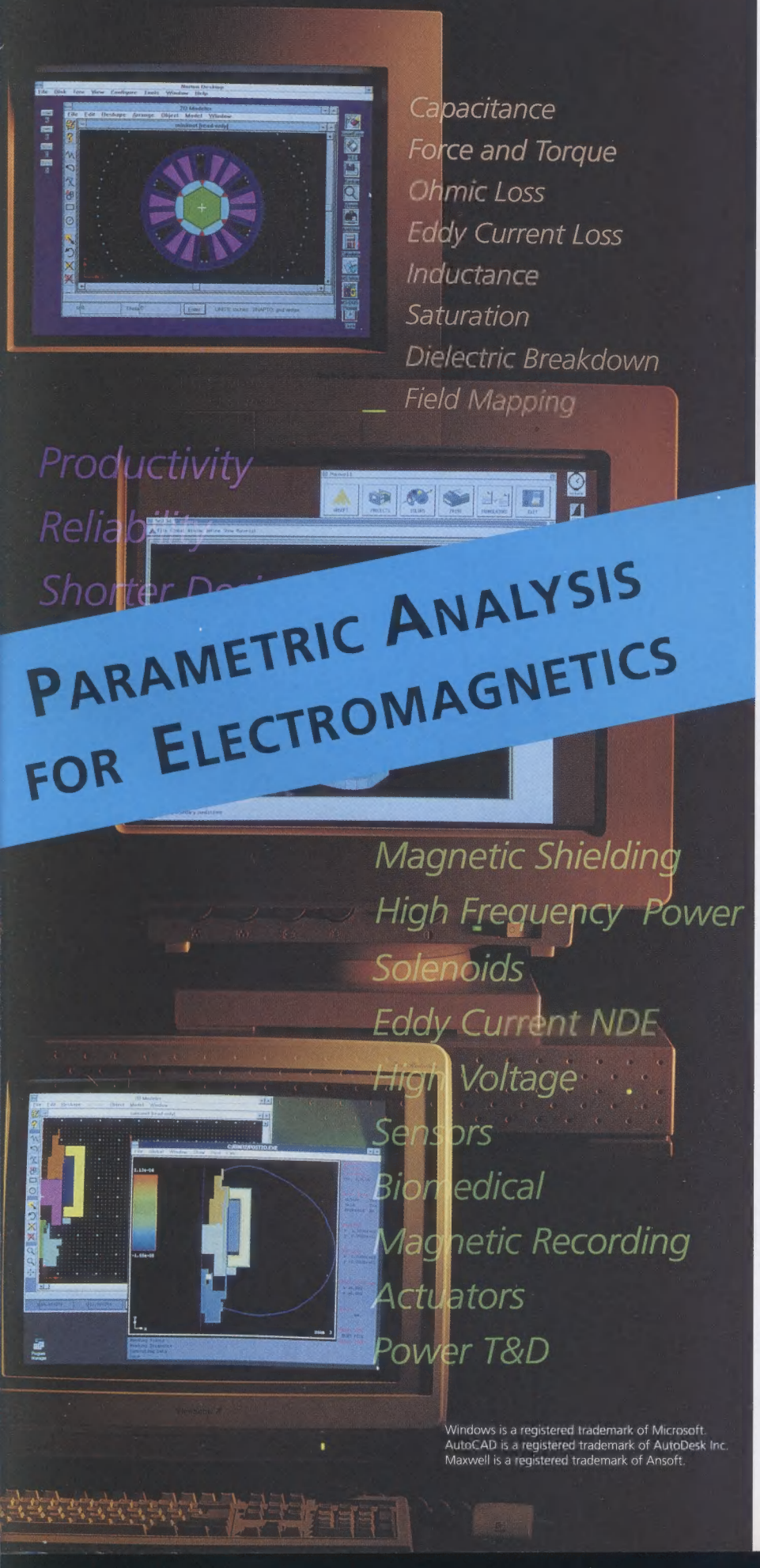
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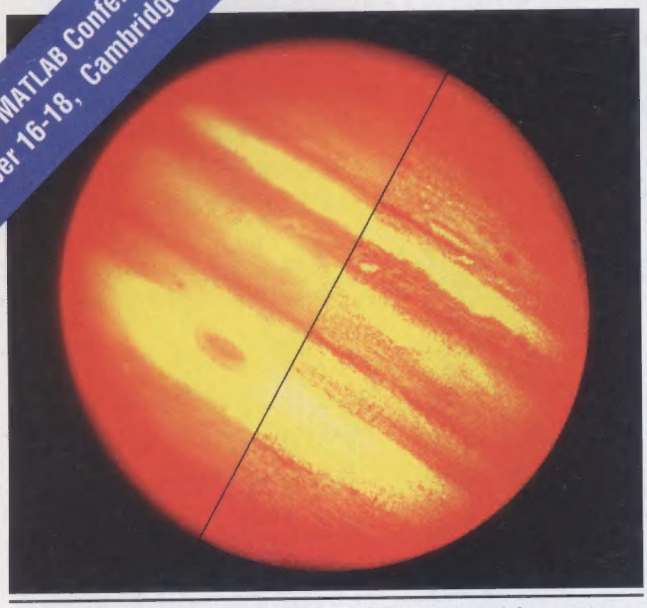
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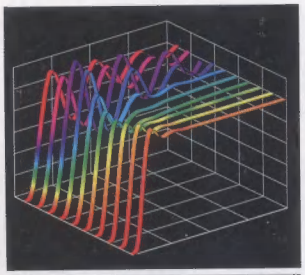
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A blurred image of Jupiter (left side), produced by the Hubble Space Telescope before its repair, was corrected with the MATLAB Image Processing Toolbox using an iterative restoration technique (right side). Data: Dr. S. J. Reeves, Auburn University.

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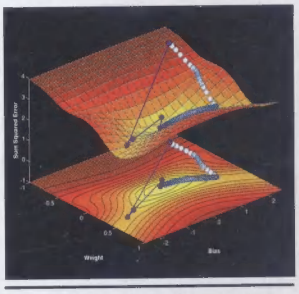
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The MathWorks is represented in the following countries:
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